7 SOURCE ASSESSMENT – TOTAL MERCURY & SUSPENDED SEDIMENT

Sources and losses of total mercury and suspended sediment are described in this chapter. The Delta mercury TMDL program addresses total mercury in addition to methylmercury because:

- Methylmercury production has been found to be a function of the total mercury content of the sediment (Chapter 3), and decreasing total mercury loads may be an option for controlling methylmercury;
- The mercury control program for the Delta must maintain compliance with the USEPA's CTR criterion of 50 ng/l for total recoverable mercury for freshwater sources of drinking water developed for human protection; and
- The mercury TMDL for San Francisco Bay assigns a total mercury load reduction to the Central Valley watershed to protect human and wildlife health in the San Francisco Bay (Johnson and Looker, 2004). The San Francisco Bay mercury control program approved by the State Water Board requires a reduction of 110 kg/yr of mercury from all sources entering the Delta or in water moving past Mallard Island. Meeting the San Francisco Bay goal will require a quantitative understanding of mercury and sediment loads entering and leaving the Delta.

Sections 7.1 and 7.2 describe mercury and suspended sediment concentrations (measured as total suspended solids, or TSS) for Delta sources and sinks and identify major data gaps and uncertainties. Input and loss loads were calculated for WY2000-2003, a relatively dry period corresponding to the available methylmercury data. In addition, the WY1984-2003 period was evaluated to determine mass balances for a more typical hydrologic period. This 20-year period includes a mix of wet and dry years that is statistically similar to what has occurred in the Sacramento Basin since accurate water records began to be collected (about 100 years). An assessment of mass balances during a typical distribution of wet and dry water years is critical because transport of sediment and mercury is a function of water velocity and volume.

Section 7.3 presents the total mercury and suspended sediment mass budgets based on the input and export loads described in Sections 7.1 and 7.2. Section 7.4.1 reviews the mercury-to-TSS ratio (TotHg:TSS) for each input and export site to identify areas that may be the focus of future remediation efforts to reduce total mercury loading. Finally, Section 7.4.2 evaluates compliance with the CTR.

7.1 Total Mercury and Suspended Sediment Sources

The following were identified as sources of total mercury and suspended sediment to the Delta: tributary inflows from upstream watersheds, municipal wastewater, atmospheric deposition, and urban runoff. Table 7.1 lists the estimated loads associated with each source for WY2000-2003 and WY1984-2003.

Table 7.1: Average Annual Total Mercury and TSS Source Loads for WY2000-2003 and WY1984-2003.

	WY2000-2003				WY1984-2003			
	TotHg		TSS		TotHg		TSS	
	kg/yr ± 95% CI	% of All Inputs	Mkg/yr ± 95% CI	% of All Inputs	kg/yr ± 95% CI	% of All Inputs	Mkg/yr ± 95% CI	% of All Inputs
Tributary Inputs [a, b]								
Sacramento River	146 ±1	66%	689 ±7	64%	183 ±1	45%	865 ±7	40%
Prospect Slough	37 ±1	17%	197 ±5	18%	169 ±5	42%	1,014 ±31	47%
San Joaquin River	18 ±2	8.2%	138 ±23	13%	29 ±4	7.2%	223 ±37	10%
Calaveras River	3.8 ±2	1.7%	15 ±21	1.4%	4.1 ±2	1.0%	16 ±23	0.7%
Mokelumne-Cosumnes Rivers	2.8 ±0.6	1.3%	7.7 ±2	0.7%	4.6 ±1	1.1%	12 ±3	0.6%
Ulatis Creek	2.1 ±2	1.0%	16 ±19	1.5%	2.2 ±2	0.5%	17 ±19	0.8%
French Camp Slough	1.6 ±3	0.7%	2.3 ±2	0.2%	1.7 ±3	0.4%	2.4 ±2	0.1%
Morrison Creek	0.79 ±0.2	0.4%	4.3 ±2	0.4%	0.83 ±0.2	0.2%	4.5 ±2	0.2%
Marsh Creek	0.54 ±0.01	0.3%	1.1 ±11	0.1%	0.54 ±0.01	0.1%	1.1 ±11	0.1%
Bear/Mosher Creeks	0.29 ±0.2	0.1%	2.4 ±5	0.2%	0.30 ±0.2	0.1%	2.4 ±5	0.1%
Sum of Tributary Sources:	**213 ±4**	**97%**	**1,073 ±28**	**99%**	**395 ±7**	**98%**	**2,157 ±51**	**>99%**
Inputs within the Delta/Yolo Bypass								
Wastewater	2.5	1.1%			2.5	0.6%		
Urban	2.3	1.1%	7.5	0.7%	2.4	0.6%	7.8	0.4%
Atmospheric (Indirect)	1.5	0.7%			1.5	0.4%		
Atmospheric (Direct)	0.81	0.4%			0.84	0.2%		
Sum of Within-Delta Sources:	**7.1**	**3%**	**7.5**	**1%**	**7.2**	**2%**	**7.8**	**<1%**
TOTAL INPUTS:	**220 ±4**		**1,080 ±28**		**403 ±7**		**2,165 ±51**	

(a) Confidence intervals (CI) were calculated for the average annual loads for inputs with daily flow data. See Appendix I for the calculation methods.

(b) Total mercury and TSS concentrations are not available for several small drainages to the Delta, including the following areas shown on Figure 6.1: Dixon, Upper Lindsay/Cache Slough, Manteca-Escalon, Bethany Reservoir, Antioch, and Montezuma Hills areas.

7.1.1 Tributary Inputs

During WY2000-2003, tributaries to the Delta contributed approximately 97% of the mercury and 99% of the suspended sediment (Table 7.1). The Sacramento Basin alone (Sacramento River at Freeport + Yolo Bypass) contributed more than 80% of all mercury and TSS loads. The load estimates in Table 7.1 are based on the water volumes described in Section 6.1 and Appendix E and concentration data collected by several agencies provided in Appendix L.

Central Valley Water Board staff began evaluating mercury loads from the Sacramento River watershed and Yolo Bypass in 1994 (Foe and Croyle, 1998). From March 2000 to September 2001, staff conducted monthly sampling at the Delta's four major tributary input sites (Foe, 2003): Sacramento River; San Joaquin River; Mokelumne River (downstream of the Mokelumne/Cosumnes Rivers confluence); and Prospect Slough at Toe Drain in the Yolo Bypass. In addition, other programs conducted periodic aqueous sampling between 1993 and 2003 on the Sacramento River (SRWP, 2004; CMP, 2004; Stephenson *et al.*, 2002). Central Valley Water Board staff resumed sampling in April 2003. Figure 6.2 shows the tributary monitoring locations. Table 7.2 and Figures I.1 through I.6 in Appendix I summarize the available mercury and TSS data.

Sections 7.1.1.1 through 7.1.1.3 describe the methods used to estimate the loads for the Delta's tributary watersheds and identify uncertainties. Because the Sacramento Basin is the primary source of mercury to the Delta, Section 7.1.1.3 provides an analysis of loading from major upstream Sacramento River tributaries. This information may be valuable for designing follow-up studies to determine where to implement mercury control programs.

7.1.1.1 Sacramento Basin Inputs to the Delta

Sacramento Basin mercury and TSS discharges to the Delta were determined for the Sacramento River at Freeport and the Yolo Bypass at Prospect Slough. Mercury and TSS concentrations for the Sacramento River at Freeport were regressed against Freeport flow to determine if a relationship might exist. Both regressions were statistically significant ($P< 0.01$) indicating that it is possible to predict Sacramento River mercury and TSS concentrations from flow. The mercury/flow and TSS/flow equations were used to predict average annual loads[37,38]. The methods used to calculate the 95% confidence intervals are described in Appendix I. The average annual load for the Sacramento River was 146 kg mercury and 689 Mkg TSS for WY2000-2003, and 183 kg mercury and 865 Mkg TSS for WY1984-2003 (Table 7.1).

Prospect Slough is a major channel draining the Yolo Bypass. Total mercury and TSS samples were collected in Prospect Slough during outgoing tides. Mercury and TSS concentrations observed on dates with net outflow were regressed against daily outflows at Lisbon Weir lagged by one day[39] to determine if statistically significant correlations might exist (Section E.2.2 in Appendix E and Figure I.1 in Appendix I). Extremely high mercury and TSS concentrations were measured on 10 and 11 January 1995 (Figure I.1). These values were not included in the regressions because, as described in Section E.2.2, the hydrologic conditions that caused them appear to have occurred only once during the WY1984-2003 study period. The TotHg/flow and TSS/flow regressions for Prospect Slough were significant ($P< 0.01$, Figure I.7a and I.7b), indicating that the concentrations of both constituents could be predicted from flow. The

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[37] For all tributaries with statistically significant TotHg/flow or TSS/flow relationships, the predicted concentrations were multiplied by daily flow volumes to estimate daily loads. The estimated daily loads were summed and then divided by the number of years in the study period to estimate the average annual loads for WY2000-2003. If a flow record had dates with missing values, the data were normalized to estimate annual loads. For example, a 20-year record would be normalized by dividing 7305 (the number of days in the 20-year period) by the number of days with a recorded value in the flow record and then multiplying the resulting quotient by the calculated sum of loads; the result was then divided by 20 to obtain the average annual load.

[38] The Delta area that drains to the 13-mile reach of the Sacramento River between Freeport (near river mile 46) and the I Street Bridge (the northernmost legal Delta boundary, near river mile 59) is predominantly urban and is encompassed by the urban load estimate described in Section 5.2.5. No attempt was made to subtract this area from the Sacramento River watershed load estimate. Therefore, the Sacramento River load noted in Table 7.1 incorporates a small portion of the within-Delta urban runoff loading.

[39] The estimated daily flows from Lisbon Weir on Toe Drain were lagged one day to address the approximate residence time of water along the ~15 miles between Lisbon Weir and Prospect Slough. During drier years, there may be little-to-no net outflow from the Yolo Bypass's Toe Drain downstream of Lisbon Weir between April and November. (See Appendix E for a description of Yolo Bypass hydrology.) Therefore, although sampling of Prospect Slough took place during outgoing tides with the intent of sampling outflows from the Yolo Bypass, during the summer months this sampling most likely represents waters tidally-pumped northward from Cache Slough, rather than outflows from the Yolo Bypass north of Lisbon Weir.

regressions were used to estimate annual average loads of 37 kg mercury and 197 Mkg TSS for WY2000-2003 and 169 kg mercury and 1,014 Mkg TSS for WY1984-2003 (Table 7.1). The five-fold increase in loads during the wetter WY1984-2003 years illustrates the importance of basing load calculations on the long-term average hydrology of the basin.

All other studies that have evaluated mercury and sediment loads from the Sacramento Basin are summarized in Table 7.3. The Sacramento watershed is the major source of water, mercury, and sediment to the Delta. The results confirm that export from the watershed is strongly a function of water year type. The lowest mercury export rate occurred during the driest study period (94.8 kg/yr; Foe 2003), while the highest (801 kg/yr; Foe and Croyle, 1998) was during a very wet period. Most annual loading rates fall between 200 and 500 kg of mercury per year.

The WY1984-2003 mercury-loading rate of 349±7 kg/yr is midway between these values. The most comparable study is likely that of LWA (2002), which estimated an export rate of 306 kg/yr of mercury for another relatively similar 20-year hydrologic period. The difference between the two 20-year periods, while statistically significant, is only about 10%. Interestingly, the Sacramento River is the primary source of mercury to the Delta during dry years, but exports from the Yolo Bypass increase and become comparable to Sacramento River loads during wet periods.

Sediment transport is also strongly a function of water year type (Table 7.3). The smallest export rate occurred during the driest period studied (568 Mkg/yr, Foe, 2003), while the highest rate happened during a wet year (3,900 Mkg/yr, Foe and Croyle, 1998). The WY1984-2003 sediment export rate of 1,894 ±32 Mkg/yr is among the higher reported. The importance of the Yolo Bypass, like for mercury, is strongly a function of flow. The Bypass only exports a small amount of sediment during dry periods, but loads increase and equal or exceed those of the Sacramento River during wet periods.

The sediment yield of the Sacramento Basin is reported to have declined by about 50% since 1957 (Wright and Schoellhamer, 2004). Primary causes are believed to be the reduced supply of erodible material since cessation of hydraulic mining and increased trapping of sediment in reservoirs. Therefore, future Sacramento Basin mercury and sediment export rates may be different than those computed with the present rating curves.

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Table 7.2: Total Mercury and TSS Concentrations for Tributary Inputs

Site [a]	# of Samples	Sampling Begin Date	Sampling End Date	Min. Conc.	Ave. Conc.	Median Conc.	Max. Conc.
TOTAL MERCURY CONCENTRATIONS (ng/l)							
Bear/Mosher Creeks [b]	4	3/15/03	2/26/04	3.55	8.08	8.70	11.36
Calaveras River @ RR u/s West Lane [b]	4	3/15/03	2/26/04	13.23	20.53	21.34	26.22
French Camp Slough near Airport Way	5 [4]	7/11/00	2/26/04	1.73 [3.32]	16.75 [20.5]	4.71 [11.63]	55.42 [55.42]
Marsh Creek @ Hwy 4	19 [3]	11/05/01	2/02/04	0.93	7.34	4.36	30.18
Mokelumne River @ I-5	21	3/28/00	9/30/03	0.26	5.34	5.19	12.28
Morrison Creek [c]	47 [15]	4/09/97	1/28/02	1.62 [3.9]	7.96 [10.46]	7.23 [9.12]	19.75 [19.75]
Prospect Slough (Yolo Bypass) [d]	28 [26]	1/10/95	9/30/03	10.58	73.22 (30.80)	26.70 (25.73)	695.6 (92.2)
Sacramento River @ Freeport	155	2/15/94	11/06/02	1.20	8.28	6.31	36.19
San Joaquin River @ Vernalis	34	10/29/93	2/26/04	3.12	7.99	7.33	21.73
Ulatis Creek near Main Prairie Rd	6 [4]	1/28/02	2/26/04	1.34 [24.21]	36.06 [53.24]	28.68 [52.51]	83.74 [83.74]
TSS CONCENTRATIONS (mg/l)							
Bear/Mosher Creeks [b]	4	3/15/03	2/26/04	15.8	65.8	24.1	199.1
Calaveras River @ RR u/s West Lane [b]	4	3/15/03	2/26/04	32.4	82.7	55.4	187.5
French Camp Slough near Airport Way	5 [4]	1/28/02	2/26/04	12.0 [16.7]	26.0 [29.5]	26.4 [27.5]	46.5 [46.5]
Marsh Creek @ Hwy 4	7 [2]	3/15/03	2/02/04	17.9 [36.9]	69.1 [155.0]	36.9 [155.0]	273.2 [273.2]
Mokelumne River @ I-5	23	3/28/00	9/30/03	5.8	14.5	12.0	31.0
Morrison Creek [c]	44 [15]	4/09/97	1/28/02	6.0 [7.0]	39.9 [57.0]	27.0 [40.5]	140 [140]
Prospect Slough (Yolo Bypass) [d]	26 [24]	1/10/95	9/30/03	36.6	298.4 [166.8]	143.2 [139.9]	2300.7 [512.7]
Sacramento River @ Freeport	187	12/15/92	1/20/04	<0.5	38.0	26.0	368.0
San Joaquin River @ Vernalis	29	3/28/00	2/26/04	20.0	61.1	56.0	170.8
Ulatis Creek near Main Prairie Rd.	6 [4]	1/28/02	2/26/04	2.5 [140.2]	276.5 [411.6]	217.8 [338.4]	829.6 [829.6]

(a) Flow gage data were not available for most of the small tributary outflows to the Delta. Therefore, wet weather concentration data (noted in brackets) and estimated wet weather runoff (Section E.2.3 in Appendix E) were used to develop load estimates.

(b) Only wet weather events were sampled on the Calaveras River and Bear and Mosher Creeks in Stockton. The one wet weather Mosher Creek sample result was combined with the Bear Creek data to estimate loads for both creeks (Appendix I).

(c) Concentration data collected at multiple sites on lower Morrison Creek were compiled to develop load estimates (Appendix I).

(d) Sampling took place at Prospect Slough (export location of the Yolo Bypass) both when there were net outflows from tributaries to the Yolo Bypass and when there was no net outflow (i.e., the slough's water was dominated by tidal waters from the south). The regression analysis focuses only on the conditions when there was net outflow from the Yolo Bypass. The above values do not include data collected when there was no net outflow. The values in parentheses are from calculations without the two very high values shown in Figure I.1. The regression is between total mercury concentrations observed at Prospect Slough (not including the two very high values shown in Figure I.1) and total export flows for the previous day estimated for Lisbon Weir, approximately 15 miles north of the Prospect Slough sampling station. The previous day's flow values were used to address the approximate residence time of the water as it travels through the Yolo Bypass to the export location where samples were collected.

Table 7.3: Comparison of Load Estimates for Sacramento Basin Discharges to the Delta

Study	Sampling Location	Period	Average Sacramento Valley Water Year Hydrologic Index [(a)]	Average Annual TotHg Load [± 95 CI] (kg)	Average Annual TSS Load [95% CI] (Mkg)
Sacramento River					
Delta Mercury TMDL [(b)]	Freeport	WY2000-2003	7.3	146 ± 1	689 ± 7
		WY1984-2003	7.8	183 ± 1	865 ± 7
Foe and Croyle (1998)	Greene's Landing	May 1994- April 1995	12.9	426	1,400
Foe (2003)	Greene's Landing	WY2001 [(c)]	5.8	91	526
LWA (2002)	Freeport	WY1980-1999	8.5	189 ± 2	na
Wright & Schoellhamer (2005)	Freeport	WY1999-2002	7.7	na	1,100 ± 170
Yolo Bypass					
Delta Mercury TMDL	Prospect Slough	WY2000-2003	7.3	37 ± 1	197 ± 5
		WY1984-2003	7.8	169 ± 5	1,014 ± 31
Foe and Croyle (1998)	Prospect Slough	May 1994- April 1995	12.9	375	2,500
Foe (2003)	Prospect Slough	WY2001 [(c)]	5.8	3.8	42
LWA (2002)	Woodland	WY1980-1999	8.5	118 ± 17	na
Wright & Schoellhamer (2005)	Woodland	WY1999-2002	7.7	na	310 ± 130
Sacramento Basin Total (Sacramento River + Yolo Bypass)					
Delta Mercury TMDL		WY2000-2003	7.3	183 ± 1	886 ± 9
		WY1984-2003	7.8	352 ± 5	1879 ±31
Foe and Croyle (1998)		May 1994- April 1995	12.9	801	3,900
Foe (2003)		WY2001 [(c)]	5.8	94.8	568
LWA (2002)		WY1980-1999	8.5	306	na
Wright & Schoellhamer (2005)		WY1999-2002	7.7	na	1,410 ± 300
Domagalski (2001) [(d)] 3 winter seasons, 20 December to 20 March		WY1997	10.8	487	na
		WY1998	13.3	506	na
		WY1999	9.8	169	na

(a) Source: DWR, 2006 (http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST). DWR calculated a hydrologic index for the Sacramento Valley (Section E.1 in Appendix E). "Normal" hydrologic conditions for the Sacramento Valley are represented by an index value of 7.8, "wet" ≥9.2, "dry" 5.4 to 6.5, and "critical dry" ≤5.4. Figure E.1 in Appendix E illustrates the indices for each water year for the period of record.

(b) See Appendix I for the methods used to estimate the 95% confidence intervals (CI) for the TMDL load estimates.

(c) Foe's 2003 CALFED study estimated monthly total mercury and TSS loads for March 2000 through September 2001, but did not include load estimates for November 2000. November total mercury and TSS loads for WY2001 were estimated by averaging the loads for October and December 2000.

(d) Domagalski (2001) reported winter mercury loads from the Sacramento Basin for WY1997 through 1999 based on data collected at Sacramento River at Freeport and Yolo Bypass at Interstate 80 (upstream of Putah Creek inputs), but did not report individual loads for the Sacramento River and Yolo Bypass.

7.1.1.2 Other Tributary Inputs to the Delta

The TotHg/flow and TSS/flow regressions for the Mokelumne-Cosumnes and San Joaquin Rivers were not significant ($P > 0.05$). Therefore, average mercury and TSS concentrations (Table 7.2) were multiplied by average annual water volumes for WY2000-2003 and WY1984-2003 (Table 6.1) to estimate an average annual load. The Mokelumne River has an estimated average annual load of 3 kg mercury and 8 Mkg TSS for WY2000-2003 and 5 kg mercury and 12 Mkg TSS for WY1984-2003 (Table 7.1). Similarly, the San Joaquin River has an average annual load of 18 kg mercury and 138 Mkg TSS and 29 kg mercury and 223 Mkg TSS, for WY2000-2003 and WY1984-2003, respectively.

Several other studies have estimated mercury and sediment loads from the San Joaquin and Mokelumne-Cosumnes watersheds (Table 7.4). All studies confirm that mercury loads from both basins are much smaller than from the Sacramento Basin (Table 7.3). Reported annual mercury loads for the San Joaquin range from 16 to 29 kg/yr. The WY1984-2003 mercury load is 29 ±4 kg/yr. This value is statistically similar to the 20-year load calculated by LWA (2002) of 26 kg/yr. Mercury load estimates for the Mokelumne-Cosumnes watersheds are smaller and range from 2 to 5 kg/yr. The WY1984-2003 load estimate is 5 ±1 kg/yr while the WY1980-1999 LWA (2002) estimate is 3 kg/yr. Again, both 20-year loading rates are statistically similar.

Sediment export rates (Table 7.4) are also much smaller for both the San Joaquin and Mokelumne-Cosumnes systems than for the Sacramento Basin (Table 7.3). Export rates for the San Joaquin varied between 110 and 235 Mkg/yr. The 20-year TMDL rate is the highest calculated for the Basin at 223±37 Mkg/yr. The Mokelumne-Cosumnes sediment yield is lower. The 20-year TMDL value is 12±3 Mkg/yr.

Mercury and TSS loads for Marsh Creek were estimated using flow at the Marsh Creek Brentwood gage. The Brentwood gage was not operational during WY2000. Therefore, the mercury and TSS loads in Table 7.1 were based on flow data for WY2001-2003. A statistically significant relationship was found for mercury/flow but not for TSS/flow. Mercury concentrations and loads were estimated using the regression, while TSS loads were computed by multiplying the 3-year average annual water volume by the average TSS concentration. The WY2001-2003 annual average mercury and TSS loads were 1 kg/yr and 1 Mkg/yr, respectively.

There are no flow gages on several small east and westside Delta tributaries: Morrison Creek, Bear Creek, Mosher Creek, French Camp Slough, and Ulatis Creek. Average wet season mercury and TSS concentrations (Table 7.2) were multiplied by estimated average annual rainfall runoff volumes (Table 6.1 and Section E.2.2 in Appendix E) to calculate an average annual load. The WY1984-2003 estimate of mercury and suspended sediment yield from the combination of all these small tributaries is 5 ±2 kg/yr and 26 ±13 Mkg/yr, respectively (Table 7.1).

Table 7.4: Comparison of Loading Estimates for Other Major Delta Tributaries

Study	Period	Average San Joaquin Valley Water Year Hydrologic Index [(a)]	Average Annual TotHg Load [± 95% CI] (kg)	Average Annual TSS Load [± 95% CI] (Mkg)
San Joaquin River @ Vernalis				
Delta TMDL [(b)]	WY2000-2003	2.7	18 ± 2	138 ± 23
	WY1984-2003	3.1	29 ± 4	223 ± 37
Foe (2003)	WY2001 [(c)]	2.2	16	110
LWA (2002)	WY1980-1999	3.5	26	na
Wright & Schoellhamer (2005)	WY1999-2002	2.9	na	210 ± 21
Mokelumne River downstream of Cosumnes River Confluence				
Delta TMDL	WY2000-2003	2.7	3 ± 1	8 ± 2
	WY1984-2003	3.1	5 ± 1	12 ± 3
Foe (2003)	WY2001 [(c)]	2.2	2	5
LWA (2002)	WY1980-1999	3.5	3	na
Eastside Tributaries (Cosumnes, Mokelumne & Calaveras Rivers & French Camp Slough)				
Delta TMDL	WY2000-2003	2.7	8 ± 2	25 ± 13
	WY1984-2003	3.1	10 ± 2	30 ± 14
Wright & Schoellhamer (2005)	WY1999-2002	2.9	na	36 ± 8

(a) Source: DWR, 2006 (http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST). DWR calculated a hydrologic index for the San Joaquin Valley (Section E.1 in Appendix E). "Normal" hydrologic conditions for the San Joaquin Valley are represented by an index value of 3.1, "wet" is ≥3.8, "dry" is 2.1 to 2.5, and "critical dry" is ≤2.1.

(b) See Appendix I for the methods used to estimate the 95% confidence intervals (CI) for the TMDL load estimates.

(c) Foe's 2003 CALFED study estimated monthly total mercury and TSS loads for March 2000 through September 2001, but did not include load estimates for November 2000. November total mercury and TSS loads for WY2001 were estimated by averaging the loads for October and December 2000.

7.1.1.3 Sacramento Basin Tributary Watersheds Loads

The Sacramento Basin accounts for about 80% of all mercury and TSS loading to the Delta (Table 7.1). Therefore, an evaluation was undertaken to determine the contribution of each of the major tributaries. The information may prove useful to help focus follow-up studies and implementation actions on key watersheds that contribute a disproportionate amount of mercury. During low flow, water in the Sacramento River at Freeport primarily originates from Shasta and Oroville Dams in the upper Sacramento and Feather River basins, respectively (Figure 7.1). In contrast, during large storms the Sacramento River at Freeport may be dominated by flows from the American and Feather Rivers. Storm overflow from the upper Sacramento River, Feather River, and Colusa Basin are routed down the Yolo Bypass. The Yolo Bypass also receives flows from Putah Creek and Cache Creek *via* the Cache Creek Settling Basin. The Cache Creek Settling Basin is located at the base of the Cache Creek watershed and currently captures about half of the sediment and mercury transported by Cache Creek (Foe and Croyle, 1998; CDM, 2004; Cooke *et al.*, 2004); untrapped sediment is flushed into the Yolo Bypass.

Four-year (WY2000-2003) and 20-year (WY1984-2003) average annual loading values were calculated for major tributaries to the Sacramento River. Table 7.5 summarizes the mercury and TSS concentration data. Table 7.6a, b, and c present watershed acreages, annual average export rates for water, mercury and TSS. The data were collected by the SRWP, DWR, USGS, CMP, and Central Valley Water Board staff (Appendix L). The water volume calculations are described in Appendix E. Appendix I provides time series plots of the available mercury and TSS data and TotHg/flow and TSS/flow regressions described in the following pages.

Total mercury and TSS concentrations for each tributary were regressed against flow to determine if correlations existed (Appendix I). The TotHg/flow and TSS/flow regressions for the American River, Cache Creek, Colusa Basin Drain, Feather River, Putah Creek and Sacramento River at Colusa were all significant ($P<0.05$) and were used to predict 4- and 20-year average annual loads (Table 7.6).

No daily flow or concentration data were available for Natomas East Main Drain (NEMD). Concentration data collected by the SRWP, USGS, and City of Roseville were available for Arcade Creek near Norwood, Del Paso Heights, and Dry Creek, all within the NEMD watershed. Wet weather concentration data for Arcade and Dry Creeks (noted in parentheses in Table 7.5) and estimated wet weather runoff for the entire Natomas East Main Drain watershed (Appendix E) were used to develop preliminary load estimates. The Sutter Bypass watershed includes the areas that drain into Butte Creek south of Chico and areas that drain into the Sutter Bypass between the Sacramento and Feather Rivers and south of the Sutter Buttes (Figure 7.1). In addition, flood flows from the Sacramento River upstream of Colusa are diverted into Sutter Bypass through the Moulton and Colusa bypasses; flood flows from the Sacramento River downstream of Colusa are diverted into the Sutter Bypass through the Tisdale bypass; and flood flows from the Feather River flow into the Sutter Bypass.

Floodwaters from the Sacramento River also spill at several locations into the Butte Creek basin and Butte Sink, which drain to Sutter Bypass. During low flow conditions, the Sutter Bypass drains through Sacramento Slough near Karnak into the Sacramento River less than a mile upstream of the Feather River confluence. During high flow, the Sacramento Slough channel is submerged and the Sutter Bypass has unchannelized flow directly into the Sacramento River. Sutter Bypass average annual water volumes and loads (Table 7.6) were estimated using flows from the DWR gage on Butte Slough near Meridian. The bypass at this location includes flows from Butte Creek and diversions from the Sacramento River made by Moulton and Colusa Weirs (which are upstream of the “Sacramento River above Colusa” sampling station), but not Tisdale Weir or other sources that discharge to the bypass downstream of Meridian. The WY1998-2003 flows were used to estimate long-term average mercury and TSS loads from Sutter Bypass, as only flows for these years are available for the Meridian gage. WY1998-2003 represents a relatively wetter period than the WY1984-2003, hence these load estimates may overestimate the Sutter Bypass contribution to the Delta.

Total mercury and TSS concentration data were available for the Sutter Bypass at Sacramento Slough near Karnak, about 30 miles downstream of the Meridian flow gage. The data were collected between February 1996 and September 2003 during a range of flow conditions, including when Sacramento Slough was submerged. There is a flow gage located nearby; however, it was operational only during the WY1996-1998 period. In addition, it was not rated for flows above 5,200 cfs (Figure 7.2); flows exceeded the 5,200 cfs rating curve happened for extended periods during each year. Therefore, the TotHg/flow and TSS/flow regressions for Sacramento Slough are based only on the samples collected when the Karnak gage recorded flows within its rating curve, most of which are low flow events. Not surprisingly, the TotHg/flow and TSS/flow regressions for Sacramento Slough were not statistically significant. Therefore, a preliminary estimate of Sutter Bypass loading was developed by multiplying water volumes recorded by the Meridian gage by the average total mercury and TSS concentrations observed at Karnak. This calculation does not address any uncertainty associated with using concentration data collected 30 miles downstream of the flow gage.

Four watersheds provided more than 90% of the annual average water volume of the Sacramento Basin during WY2000-2003 and WY1984-2003 (Table 7.6a). The watersheds are the Sacramento River above Colusa, Feather River, Sutter Bypass and American River. The 4 and 20-year water budgets balance within 4 to 5% indicating that all the major water sources have been identified. A different grouping of four watersheds contributed about 90% of the annual mercury load (Table 7.6b). The watersheds are the Sacramento River above Colusa, Cache Creek Settling Basin, Feather River and Sutter Bypass. The sum of tributary mercury inputs for both the 4 and 20-year periods is greater than the load exported to the Delta (Table 7.6b). Mercury exports average 79 to 87% of inputs. This suggests that either tributary loads are overestimated or that deposition is occurring in the river channel upstream of Freeport and/or in the Yolo Bypass.

The same four watersheds that contribute the majority of the mercury also export more than 90% of the sediment (Table 7.6c). The sum of tributary inputs of sediment is greater than the exports to the Delta. Exports range from 55% of inputs during WY2000-2003 to 89% during WY1984-2003. The results suggest, like for mercury, that incoming loads are either being overestimated or that deposition is occurring in the Central Valley. Wright and Schoellhamer (2005) also found that the Sacramento Basin landward of Rio Vista was depositional. However, unlike this report, they concluded that deposition was greater in wet than in dry periods.

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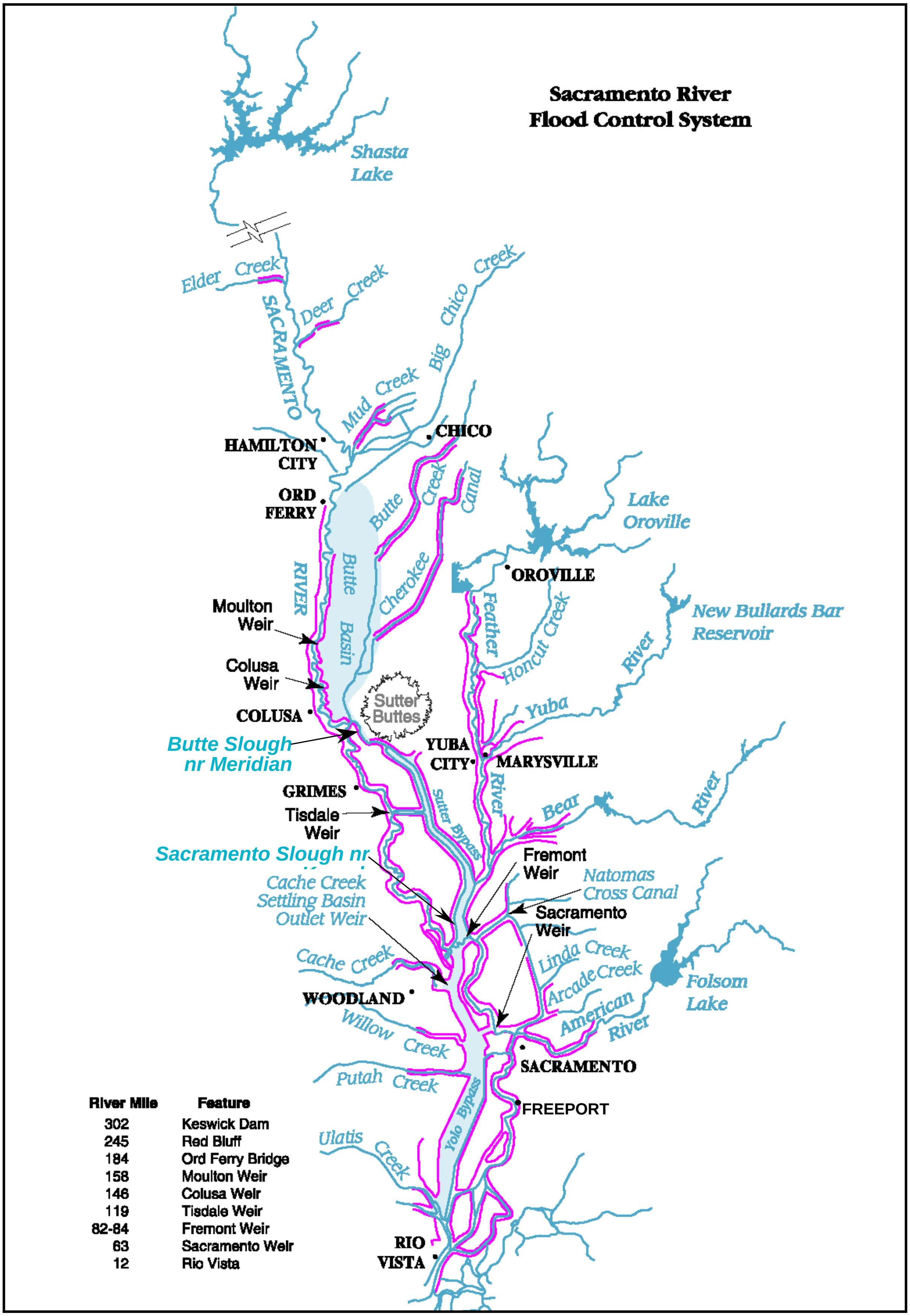

Figure 7.1: Sacramento River Flood Control System.
Pink lines represent levees. (Tetra Tech, Inc., 2005b; DWR, 2003)

Table 7.5: Total Mercury and TSS Concentrations for Sacramento Basin Tributaries.

Site	# of Samples	Sampling Begin Date	Sampling End Date	Min. Conc.	Average	Median Conc.	Max. Conc.
Total Mercury Concentrations (ng/l)							
American River @ Discovery Park	155	1/18/94	2/19/04	0.46	2.97	2.14	18.51
Cache Creek Settling Basin	26	12/23/96	2/17/04	4.07	171.89	58.24	984.60
Colusa Basin Drain	63	1/31/95	2/18/04	1.59	11.58	6.90	75.10
Feather River near Nicolaus	67	1/31/95	2/18/04	1.49	6.90	4.43	46.19
Natomas East Main Drain [(a)]	56 (12)	3/5/96	12/12/02	1.06 (9.52)	10.87 (27.78)	6.88 (20.84)	82.99 (82.99)
Putah Creek @ Mace Blvd.	36	1/31/95	3/09/04	1.25	33.02	9.14	485.00
Sacramento River above Colusa	64	3/10/95	2/17/04	0.60	12.30	4.27	105.16
Sacramento Slough near Karnak [(b)]	55	2/12/96	9/15/03	0.69	8.77	7.57	30.8
TSS Concentrations (mg/l)							
American River @ Discovery Park	191	12/15/92	2/19/04	0.5	6.23	3.0	116.0
Cache Creek d/s Settling Basin	23	12/23/96	2/17/04	41.0	425.1	140.0	1,900
Colusa Basin Drain	59	2/07/96	2/18/04	21.0	128.1	101.0	487.7
Feather River near Nicolaus	70	3/11/95	2/18/04	2.0	23.1	14.5	123.0
Natomas East Main Drain [(a)]	30 (8)	3/5/96	3/8/02	5.0 (16.6)	31.3 (43.0)	26.0 (34.5)	122.0 (96.0)
Putah Creek @ Mace Blvd.	29	3/28/00	2/29/04	1.6	59.01	30.0	417.8
Sacramento River above Colusa	48	3/10/95	2/17/04	10.0	98.6	36.0	662.2
Sacramento Slough near Karnak [(b)]	54	2/12/96	9/15/03	14.8	62.6	53.0	182.0

(a) No concentration or flow data gage data were available for Natomas East Main Drain outflows. The SRWP, USGS and City of Roseville collected total mercury and TSS concentration data on Arcade Creek near Norwood and Del Paso Heights and Dry Creek. Wet weather concentration data for Arcade Creek and Dry Creek (noted in parentheses), and estimated wet weather runoff for the entire Natomas East Main Drain watershed (Table 6.1 in Chapter 6 and Section E.2.2 in Appendix E), were used to develop preliminary load estimates. Natomas East Main Drain was recently renamed “Steelhead Creek”.

(b) Sacramento Slough near Karnak is the low flow channel for Sutter Bypass.

Table 7.6a: Sacramento Basin Tributaries – Acreage and Water Volumes.

Tributary	Acreage	% All Acreage	Water Volume (M acre-feet/yr)		% All Water	
			WY2000-2003	WY1984-2003	WY2000-2003	WY1984-2003
Upstream Tributary Inputs						
American River	1,253,740	7.5%	1.9	2.5	11%	13%
Cache Creek	724,526	4.3%	0.22	0.38	1.3%	1.9%
Colusa Basin Drain	1,577,307	9.4%	0.67	0.66	4.0%	3.4%
Coon Creek/Cross Canal	287,914	1.7%	0.089	0.094	0.5%	0.5%
Feather River	3,793,179	23%	3.9	5.3	23%	27%
Natomas East Main Drain	231,598	1.4%	0.084	0.088	0.5%	0.5%
Putah Creek	652,762	3.9%	0.041	0.11	0.2%	0.6%
Sacramento River @ Colusa	7,562,525	45%	8.2	8.1	49%	41%
Sutter Bypass	682,071	4.1%	1.8	2.3	11%	12%
Sum of Upstream Inputs:	**16,765,622**	**100%**	**16.9**	**19.5**	**100%**	**100%**
Exports to Delta						
Yolo Bypass (Prospect Slough)	- - -		1.0	2.7	6%	14%
Sacramento River (Freeport)	- - -		15.1	16.1	94%	86%
Sum of Exports to Delta:	- - -		**16.1**	**18.8**	**100%**	**100%**
Tributary Inputs – Exports to Delta:			**0.8**	**0.7**		
Exports to Delta / Tributary Inputs:			**95%**	**96%**		

Table 7.6b: Sacramento Basin Tributaries – Total Mercury Loads.

Tributary	Average Annual TotHg Load ± 95 CI [(a)] (kg/yr)		% of TotHg Inputs	
	WY2000-2003	WY1984-2003	WY2000-2003	WY1984-2003
Upstream Tributary Inputs				
American River	6.4 ±0.1	14 ±0.1	2.8%	3.4%
Cache Creek Settling Basin	26 ±3	118 ±5	11%	30%
Colusa Basin Drain	10	13	4.3%	3.3%
Feather River	28 ±1	67 ±2	12%	17%
Natomas East Main Drain	2.9 ±1	3.0 ±1	1.2%	0.8%
Putah Creek	1.0 ±0	8.8 ±1	0.4%	2.2%
Sacramento River @ Colusa	139 ±4	151 ±4	60%	38%
Sutter Bypass	19 ±3	25 ±4	8.2%	6.3%
Sum of Upstream Inputs:	**232 ±6**	**400 ±8**	**100%**	**100%**
Exports to Delta				
Prospect Slough	37 ±1	169 ±5	20%	48%
Sacramento River @ Freeport	146 ±1	183 ±1	80%	52%
Sum of Exports to Delta:	**183 ±1**	**352 ±5**	**100%**	**100%**
Trib Inputs - Exports to Delta	**49**	**48**		
Exports to Delta / Trib Inputs	**79%**	**88%**		

(a) Confidence intervals (CI) were calculated for the average annual total mercury loads for the tributary stations with daily flow gages. See Appendix I for the methods used to estimate the confidence intervals.

Table 7.6c: Sacramento Basin Tributaries – TSS Loads.

Tributary	Average Annual TSS Load ± 95% CI [(a)] (MKg/yr)		% of TSS Inputs	
	WY2000-2003	WY1984-2003	WY2000-2003	WY1984-2003
Upstream Tributary Inputs				
American River	13 ±0.2	52 ±0.5	0.8%	2.4%
Cache Creek Settling Basin	68 ±6	259 ±10	4.2%	12%
Colusa Basin Drain	117	148	7.2%	7.0%
Feather River	98 ±3	216 ±6	6.0%	10%
Natomas East Main Drain	4.5 ±2	4.7 ±2	0.3%	0.2%
Putah Creek	2.2 ±0.2	16 ±1	0.1%	0.8%
Sacramento River above Colusa	1,180 ±41	1,256 ±41	73%	59%
Sutter Bypass	138 ±21	177 ±27	8.5%	8.3%
Sum of Upstream Inputs:	**1,621 ±48**	**2,129 ±49**	**100%**	**100%**
Exports to Delta				
Prospect Slough	197 ±5	1,014 ±31	22%	54%
Sacramento River @ Freeport	689 ±7	865 ±7	78%	46%
Sum of Exports to Delta:	**886 ±9**	**1,879 ±31**	**100%**	**100%**
Trib Inputs - Exports to Delta	**735**	**250**		
Exports to Delta / Trib Inputs	**55%**	**88%**		

(a) Confidence intervals (CI) were calculated for the average annual TSS loads for the tributary stations with daily flow gages. See Appendix I for the methods used to estimate the confidence intervals.

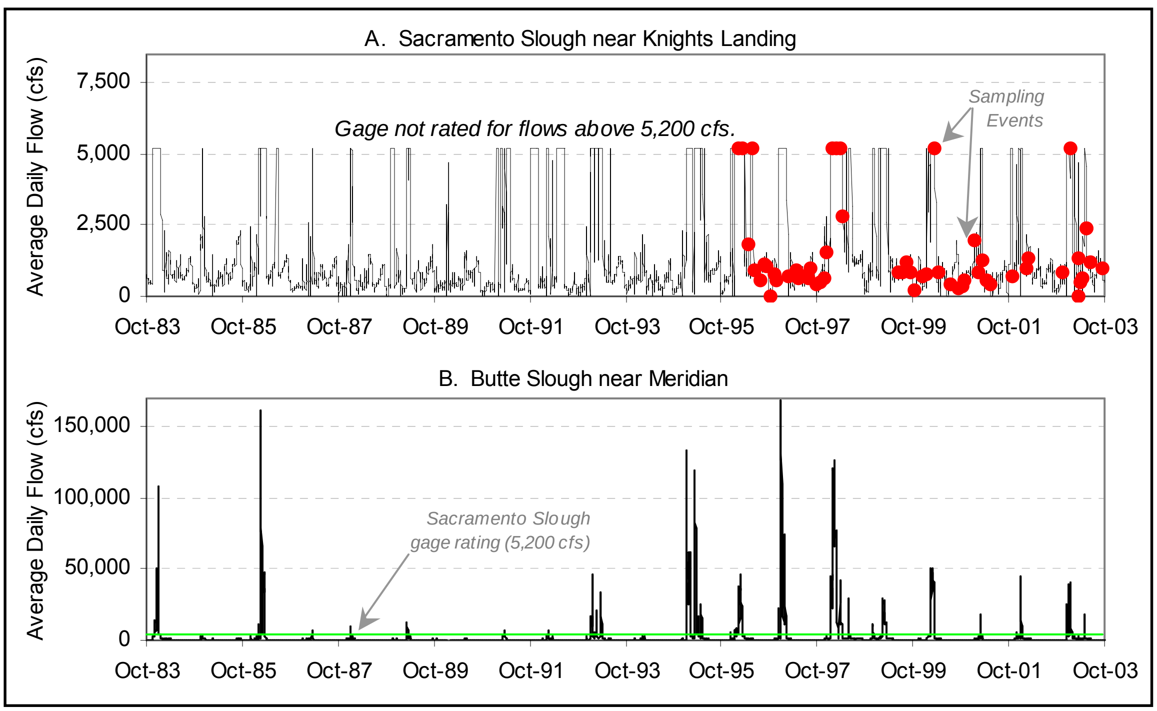

Figure 7.2: Flow Data Evaluated for Sutter Bypass.
(Note the 20-fold difference in the Y-axis flow values for these two graphs.)

7.1.2 Municipal & Industrial Sources

There are 21 NPDES-permitted municipal and industrial discharges to surface water in the Delta[40] (Figure 6.5). The sum of total mercury loads from the discharges is approximately 2.5 kg/yr, about 1% of all Delta sources (Table 7.1).

Information on average flows rates for each facility was obtained from the Central Valley Water Board's discharger project files, permits and the State Water Resources Control Board's Surface Water Information (SWIM) database. Effluent total mercury concentration data were obtained from project files and dischargers' SIP monitoring efforts.[41] Table 6.5 in Chapter 6 and Table G.1 in Appendix G provide additional information about the facilities. Table G.1 lists the estimated annual mercury loads from each facility, which were obtained from the facility-specific average effluent concentration and average daily discharge volume multiplied by 365. Appendix L provides the effluent total mercury concentration data used to calculate the average effluent total mercury loads. It was assumed that total mercury loading from the facilities does not vary substantially between wet and dry years. This consideration will be re-evaluated as additional information becomes available.

Of the 21 facilities in the Delta, two are power and heating/cooling facilities that use ambient water for cooling water: Mirant Delta LLC Contra Costa Power Plant (CA0004863) and the State of California Central Heating/Cooling Plant (CA0078581). Based on the comparison of the available intake and outfall mercury data for the Mirant Delta facility and other similar facilities that discharged to the Delta in years past (Table G.5 in Appendix G), such facilities may not act as measurable sources of mercury to the Delta. According to its NPDES permit, the Central Heating/Cooling Plant adds no chemicals to its supply water; however, the permits for Mirant Delta and other similar facilities in the tributary watersheds indicate that mercury-containing chemicals may be added to their cooling water and other low-volume waste streams may be included in their discharges (see Tables G.6 and G.7 in Appendix G). Staff recommends that the assumption that power and heating/cooling plants do not contribute mercury to Delta and upstream surface waters be re-evaluated as additional information becomes available.

[40] It is assumed that facility discharges contain negligible amounts of suspended solids.

[41] In September 2002, the Central Valley Water Board issued a California Water Code Section 13267 order to all NPDES dischargers (except municipal stormwater dischargers) requiring the dischargers to collect effluent and receiving water samples and to have the samples analyzed for priority pollutants contained in the U.S. Environmental Protection Agency's California Toxics Rule and portions of the USEPA's National Toxics Rule. This action was directed by Section 1.2 of the Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California, also known as the State Implementation Policy (SIP), which was adopted by the State Water Resources Control Board on 2 March 2000. The SIP monitoring requires that the dischargers' mercury monitoring utilize "ultra-clean" sampling and analytical methods including Method 1669 (Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels, US EPA) and Method 1631 (Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence, US EPA). The SIP monitoring requires major industrial and municipal NPDES dischargers to collect monthly samples for metals/mercury analysis, and minor industrial and municipal NPDES dischargers to collect quarterly samples.

7.1.3 Urban Runoff

Approximately 60,000 acres in the Delta are urban, most of which are regulated by NPDES waste discharge requirements. Table 6.10 in Chapter 6 lists the permits that regulate urban runoff and their corresponding acreage. Figure 6.7 shows their locations. Urban areas not encompassed by a MS4 service area were grouped into a "nonpoint source" category.

Total mercury and TSS concentration data were collected by Central Valley Water Board staff and the City and County of Sacramento from several urban waterways within or adjacent to the Delta. Figure 6.8 shows the urban areas and sampling locations, Figure H.1 in Appendix H illustrates the wet and dry weather concentrations by location, and Appendix L provides the concentration data used in Figure H.1. Data generation by analytical methods with detection limits less than 1 ng/l began in 1996. The total mercury concentrations ranged from a dry weather low of 1.06 ng/l (Arcade Creek) to a wet weather high of 1,138 ng/l (Strong Ranch Slough). The TSS concentrations ranged from a dry weather low of less than 3 mg/l (City of Sacramento Sump 111) to a wet weather high of 1,300 mg/l (Strong Ranch Slough). A visual inspection of the total mercury and TSS data suggests that the differences between the urban watersheds are not directly related to land use. Therefore, the data were averaged by wet and dry weather for each location (Table 7.7). The averages of these location-based wet and dry weather averages are assumed to represent runoff from all urban areas in or adjacent to the Delta.

To estimate wet weather mercury and TSS loads, the average wet weather concentrations were multiplied by the runoff volumes estimated for WY2000-2003 and WY1984-2003 for each MS4 area within the Delta. To estimate dry weather mercury and TSS loads, the dry weather concentrations were multiplied by the estimated dry weather urban runoff volume. Appendix E describes the methods used to estimate wet and dry weather urban runoff from urban areas within the Delta. Wet and dry weather mercury and TSS loads were summed to estimate the WY2000-2003 average annual loadings of 2.3 kg mercury and 7.5 Mkg/yr suspended sediment and WY1984-2003 average annual loadings of 2.4 kg mercury and 7.7 Mkg/yr TSS (Table 7.8). Urban land uses comprise a small portion of the Delta and contribute about 1% of the mercury load (Table 7.1). In contrast, approximately 320,000 acres of urban land – about 42% of all urban area within the Delta source region – are within 20 miles of the Delta boundary, about one day water travel time upstream. In addition, some of the urban watersheds outside the Delta discharge via sumps into Delta waterways. These discharges were not included in the Delta urban load estimate. As a result, the urban contribution to the Delta mercury load may be underestimated. To evaluate the potential contributions from upstream urban lands, the total mercury loadings from the two MS4 service areas with the greatest urban acreage immediately outside the Delta were estimated for the WY1984-2003 period. The sum of mercury loads from the Sacramento and Stockton MS4 areas may contribute more than 2% of loading to the Delta (Table 7.9). These loads are expected to increase as urbanization continues around the Delta.

Table 7.7: Summary of Urban Runoff Total Mercury and TSS Concentrations

Urban Watershed	# of Samples	Minimum Conc.	Average Conc.	Maximum Conc.
TOTAL MERCURY (ng/l)				
DRY WEATHER				
Arcade Creek	37	1.06	8.07	34.80
City of Sacramento Strong Ranch Slough	7	3.63	18.43	84.00
City of Sacramento Sump 104	7	1.61	7.78	24.30
City of Sacramento Sump 111	7	2.16	9.59	28.96
Tracy Lateral to Sugar Cut Slough	1	7.92	7.92	7.92
Average of Location Dry Weather TotHg Averages:			**10.36**	
WET WEATHER				
Arcade Creek	14	1.73	20.90	54.30
City of Sacramento Strong Ranch Slough	13	20.10	188.32	1137.90
City of Sacramento Sump 104	14	9.94	36.72	118.42
City of Sacramento Sump 111	13	10.68	28.56	65.23
Stockton Calaveras River Pump Station	5	14.18	26.07	49.71
Stockton Duck Creek Pump Station	1	13.57	13.57	13.57
Stockton Mosher Slough Pump Station	5	9.67	14.16	17.29
Stockton Smith Canal Pump Station	4	23.17	40.97	65.87
Tracy Drainage Basin 10 Outflow	3	8.78	12.13	16.12
Tracy Drainage Basin 5 Outflow	3	7.02	12.59	20.67
Tracy Lateral to Sugar Cut Slough	3	5.44	18.10	28.45
Average of Location Wet Weather TotHg Averages:			**37.46**	
TSS (mg/l)				
DRY WEATHER				
Arcade Creek	28	5.0	31.7	122.0
City of Sacramento Strong Ranch Slough	6	5.0	9.3	15.0
City of Sacramento Sump 104	7	4.0	7.6	12.0
City of Sacramento Sump 111	7	1.5	6.2	11.0
Tracy Lateral to Sugar Cut Slough	1	26.5	26.5	26.5
Average of Location Dry Weather TSS Averages:			**16.26**	
WET WEATHER				
Arcade Creek	12	7.0	99.5	320.0
City of Sacramento Strong Ranch Slough	13	23.0	208.7	1300.0
City of Sacramento Sump 104	14	31.0	104.3	270.0
City of Sacramento Sump 111	11	15.7	92.4	340.0
Stockton Calaveras River Pump Station	5	26.0	94.3	264.6
Stockton Duck Creek Pump Station	1	281.3	281.3	281.3
Stockton Mosher Slough Pump Station	5	6.0	19.6	34.0
Stockton Smith Canal Pump Station	4	76.0	125.8	184.6
Tracy Drainage Basin 10 Outflow	3	81.1	136.9	236.0
Tracy Drainage Basin 5 Outflow	3	26.1	77.5	148.1
Tracy Lateral to Sugar Cut Slough	3	6.3	153.7	342.9
Average of Location Wet Weather TSS Averages:			**126.7**	

Table 7.8: Average Annual Total Mercury and TSS Loadings from Urban Areas within the Delta/Yolo Bypass

MS4 Permittee	WY2000-2003		WY1984-2003	
	TotHg Load (kg/yr)	**TSS Load** (Mkg/yr)	**TotHg Load** (kg/yr)	**TSS Load** (Mkg/yr)
Contra Costa County	0.60	1.9	0.62	2.0
Lathrop	0.032	0.10	0.033	0.11
Lodi	0.006	0.021	0.007	0.022
Port of Stockton	0.047	0.15	0.049	0.16
Rio Vista	0.002	0.005	0.002	0.005
Sacramento MS4 Permit Area	0.21	0.68	0.22	0.71
San Joaquin Co MS4 Permit Area	0.35	1.2	0.37	1.2
Solano County	0.019	0.062	0.020	0.065
Stockton MS4 Permit Area	0.47	1.5	0.49	1.6
Tracy	0.21	0.69	0.22	0.72
West Sacramento	0.21	0.68	0.21	0.71
Yolo County	0.050	0.16	0.051	0.17
Urban Nonpoint Source (a)	0.10	0.33	0.10	0.33
Grand Total	2.3	7.5	2.4	7.8

(a) Urban areas not encompassed by a MS4 service area were grouped into a "nonpoint source" category within each Delta subarea.

Table 7.9: Comparison of WY1984-2003 Annual Delta Mercury and TSS Loads to Sacramento and Stockton Area MS4 Loads.

MS4 Service Area (a)	**Water Volume** (M acre-feet) (b)	**TotHg Load** (kg/year)	**TSS Load** (Mkg/yr)
Sacramento MS4 Urban Total	0.19	7.4	24
Stockton MS4 Urban Total	0.026	1.0	4.0
Total Delta Inputs (c)	23	400	1,080
Stockton & Sacramento Urban Runoff as % of Total Delta Inputs	**1.0%**	**2.1%**	**1.3%**

(a) The Sacramento and Stockton Area MS4s are the two MS4 service areas with the greatest urban acreage immediately upstream of the Delta, with urban land use areas of 160,000 and 25,000 acres, respectively.

(b) Refer to Appendix E for urban runoff volume estimates for wet and dry weather, which were summed to estimate the annual average water volumes shown above.

(c) These values represent the sum of all tributary and within-Delta total mercury and TSS sources shown in Table 7.1.

7.1.4 Atmospheric Deposition

Atmospheric deposition of mercury has not been measured in the Delta. Figure 7.3 illustrates wet deposition sampling locations in northern and central California, Appendix L provides the available total mercury concentration data, and Table 7.10 summarizes the data. Volume-weighted average total mercury concentrations ranged from 4.1 ng/l at Covelo to 13 ng/l at Sequoia National Park. To estimate wet deposition, the volume-weighted average concentration observed at the North Bay/Martinez station (7.4 ng/l) was used because the station is closest to, and typically upwind of, the Delta. Total mercury loading from precipitation on surface water in the Delta (direct deposition) was estimated by multiplying the average mercury concentration in North Bay/Martinez rainwater (Table 7.10) by the average rainfall volume to fall on Delta water surfaces during WY2000-2003. Loading from runoff of mercury-contaminated rain falling on land (indirect deposition) was estimated by multiplying the average mercury concentration in rainwater by the estimated runoff volume from non-urbanized land surfaces for WY2000-2003. Runoff from urban areas was not included because it is inherently incorporated in the estimates for loading from urban runoff described in Section 7.1.3. Appendix E describes the method used to estimate rainfall runoff volumes for the Delta. Table 7.11 lists the estimated mercury loads from direct and indirect wet deposition. Wet deposition (2.3 kg/yr) contributes approximately 1% of all mercury entering the Delta (Table 7.1).

There are several uncertainties inherent in the estimates of direct and indirect wet atmospheric deposition in the Delta. For example, the concentration of mercury in rain in the Delta has not been measured and runoff coefficients have not been calculated to determine how much mercury falling on land is carried into surface water. However, these uncertainties are unlikely to have a substantial impact on the overall mercury budget for the Delta (Table 7.1) because atmospheric inputs account for only about 1% of the total mass balance.

Dry mercury deposition rates were not estimated for the Delta because there is no information on airborne particulate mercury concentrations. SFEI (2001) estimated that about five times more mercury is deposited on an annual basis in dry than in wet deposition in San Francisco Bay. If so, direct dry deposition rates in the Delta may be about 12 kg/yr or about 1 to 2% of the annual load. Dr. Gill (Texas A&M University) is currently measuring wet and dry mercury deposition rates in the Central Valley as part of CALFED project ERP-02-C06-B. The study will be completed and a report published in 2008.

In an attempt to identify local – and therefore potentially controllable – sources of mercury in atmospheric deposition in the Delta and its tributary watersheds, mercury loads emitted by facilities that report emissions to the California Air Resources Board (ARB) were reviewed. The ARB Emission Inventory Branch tracks mercury loading in air emissions in its California Emission Inventory Development and Reporting System database. ARB staff provided a database describing facilities that reported mercury emissions in 2002. Appendix J provides a summary of the types of facilities in each watershed and their estimated loads. The data indicate that almost 10 kg of mercury were released in the Delta by sugar beet facilities, electric services, paper mills, feed preparation, and rice milling. Cement and concrete manufacturing facilities and crematories in the Delta's tributary watersheds appear to have relatively high mercury emissions. These loads are not incorporated in the mass budgets because their deposition rates are not known. Local air emissions of mercury warrant additional research.

Table 7.10: Summary of Available Data Describing Mercury Concentrations in Wet Deposition in Northern and Central California.

Study [a]	Station	Volume-Weighted Average TotHg Conc. (ng/l)	# of Samples	Collection Period
San Francisco Bay Atmospheric Deposition Pilot Study (SFBADPS) [b]	North Bay	7.4	14	Aug. 1999 – Jul. 2000
	Central Bay	6.6	16	
	South Bay [c]	9.7	29	
National Atmospheric Deposition Program (NADP) Mercury Deposition Network (MDN)	San Jose [c]	10	86	Jan. 2000 – Dec. 2003
	Sequoia National Park [d]	13	5	Jul. 2003 – Dec. 2003
	Covelo [e]	4.1	60	Jan. 1998 – Sep. 2000

(a) Sources: NADP MDN – Sweet, 2000; NADP, 2004. SFBADPS – SFEI, 2001. Volume weighted average total mercury concentrations for the South Bay, Central Bay, and North Bay sites were calculated by the SFEI authors (SFEI, 2001). Volume weighted average total mercury concentrations for the San Jose, Sequoia National Park, and Covelo sites were calculated by Central Valley Water Board staff from the NADP data provided in Appendix L.

(b) The North Bay, Central Bay, and South Bay sites are located at Martinez, Treasure Island and Moffett Federal Airfield/NASA Ames Research Center near San Jose, respectively.

(c) In addition to being part of the SFBADPS, the South Bay site also became one of the NADP MDN stations. Co-location of mercury wet deposition sampling under the MDN/NADP with the Pilot Study at the South Bay site began in January 2000 and resulted in ten replicate field precipitation samples.

(d) Sequoia National Park is in the Sierra Nevada Mountains to the southeast of Fresno in the Tulare Basin, which is south of the San Joaquin Basin.

(e) Covelo is ~150 miles north of San Francisco Bay in the Coast Range.

Table 7.11: Average Annual Total Mercury Loads from Wet Deposition [a]

Period/Deposition Type [b]	WY2000-2003		WY1984-2003	
	Water Volume (acre-feet) [c]	TotHg (kg/year)	Water Volume (acre-feet) [c]	TotHg (kg/year)
Direct Deposition	88,669	0.81	91,960	0.84
Indirect Deposition	159,394	1.5	165,325	1.5
TOTAL	248,063	2.3	257,284	2.3

(a) The volume-weighted average concentration observed in the North Bay/Martinez (7.4 ng/l, Table 7.10) was used to estimate total mercury loading to the Delta.

(b) Direct deposition results from mercury-contaminated rain falling on Delta/Yolo Bypass surface waters. Indirect deposition results from runoff of mercury-contaminated rain falling on land surfaces in the Delta. Runoff from urban areas was not included because it is inherently incorporated in the estimates for loading from urban runoff described in Section 7.1.3.

(c) Refer to Appendix E for a description of the methods used to estimate rainfall runoff volumes.

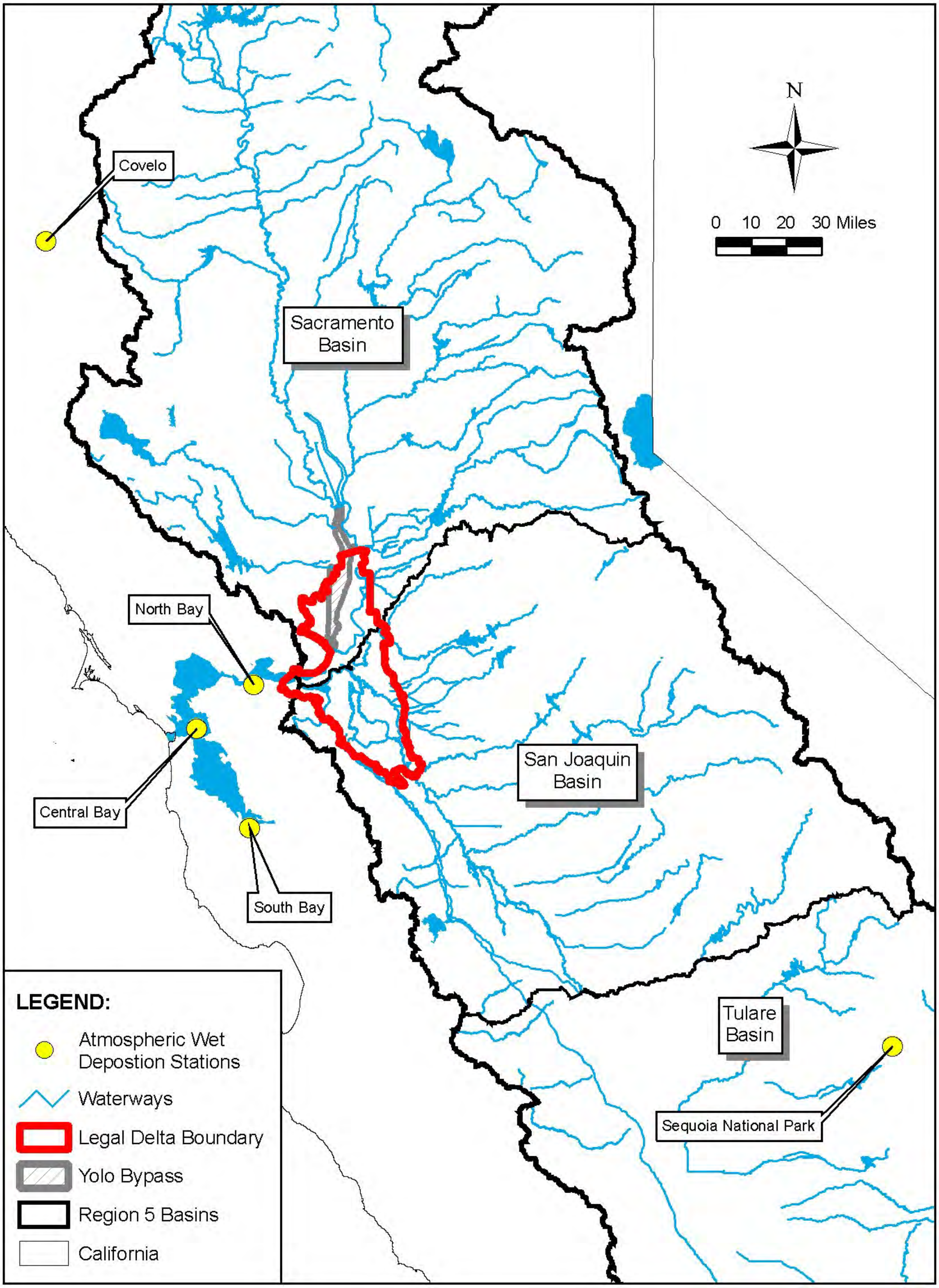

Figure 7.3: Wet Deposition Total Mercury Sampling Locations in Northern and Central California.

7.1.5 Other Potential Sources

Loading from Delta soils has not been evaluated. More than 70% of Delta lands have agricultural land uses and many of the urban areas in the Delta were once agricultural. Farming began in the Delta in 1849, about the same time that gold mining began in the Sierra Nevada Mountains (DWR, 1995). In 1861, the California legislature authorized the Reclamation District Act, which allowed drainage of Delta swampland and construction of levees; the extensive Delta levee system was mostly built between 1869 and 1880 (DWR, 1995). By 1852, hydraulic mining was the most common method for mining the placer gold deposits in the Sierra Nevada (Hunerlach *et al*., 1999) and continued until the Sawyer Decision outlawed the practice in 1884. Hydraulic gold mining resulted in the deposition of large amounts of silt and sand in Delta channels and upstream rivers (DWR, 1995). Much of these deposits may have been contaminated with mercury used to amalgamate gold. Therefore, some levees and Delta islands may have been constructed with mercury-contaminated sediment.

Barley and other grains have historically been common rotational crops in the Delta (Weir, 1952), and the seeds were treated with mercury-based fungicides before sowing (LWA, 2002). It is not known how much mercury was used in the Delta, but up to 38,000 kg of mercury may have been added in fungicides in the Sacramento Valley between 1921 and 1971 (LWA, 2002). Mercury is no longer used as an active ingredient in any pesticides (DPR, 2002).

Mercury has been measured in six soil samples in the Delta source region, mostly from agricultural fields (Bradford *et al.*, 1996). One sample was collected in the eastern Delta near White Slough north of Stockton (0.27 mg/kg) and five samples were collected within 10 miles of the Delta boundary (0.25, 0.34, and three results <0.2 mg/kg). The study authors concluded that there was no relationship between soil mercury levels and location and soil type. Some of the mercury concentrations are elevated above the proposed San Francisco Bay TMDL sediment objective of 0.2 mg/kg indicating that erosion in the Delta area may contribute to exceedances of the Bay area sediment objective.

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7.2 Total Mercury and TSS Losses

The following were identified as processes contributing to mercury loss in the Delta: flow to San Francisco Bay, water diversions to areas south of the Delta, removal of dredged sediments, and evasion of elemental mercury. Table 7.12 summarizes mercury and TSS losses by type.

Table 7.12: Average Annual Total Mercury and TSS Losses for WY2000-2003 and WY1984-2003.

	WY2000-2003				WY1984-2003			
	TotHg		TSS		TotHg		TSS	
	Load ± 95% CI (kg/yr)	% of All Losses	Load ± 95% CI (Mkg/yr)	% of All Losses	Load ± 95% CI (kg/yr)	% of All Losses	Load ± 95% CI (Mkg/yr)	% of All Losses
Outflow to San Francisco Bay	270 ±93	71%	930 ±283	67%	379 ±132	78%	1,309 ±398	75%
Dredging	57 ±71	15%	349	25%	57 ±71	12%	349	19%
Evasion	30	8%	- -	--	30	6%	--	--
State Water Project [(a)]	11 ±3	3%	46 ±22	3%	9 ±3	2%	38 ±18	2%
Delta Mendota Canal [(a)]	11 ±1	3%	62 ±9	5%	10 ±1	2%	60 ±9	4%
Sum of Losses	**379 ±112**	**100%**	**1,387 ±271**	**100%**	**485 ±143**	**100%**	**1,756 ±381**	**100%**

(a) The 95% confidence intervals (CI) were calculated for the State Water Project and Delta Mendota Canal loads using the method described in Appendix I.

7.2.1 Outflow to San Francisco Bay

Estimates of mercury and sediment exports from the Delta to San Francisco Bay are critical components of the Delta mercury TMDL for two reasons. First, outflow to San Francisco Bay is the primary export from the Delta and must be accurately measured to determine whether the Delta is a net source or sink for mercury and sediment. Second, the San Francisco Bay mercury TMDL assigned the Central Valley a mercury load allocation of 330 kg/yr. The allocation must be met either at Mallard Island or by a 110 kg reduction in incoming mercury loads to the Delta (Section 2.4.2.3).

Central Valley Water Board staff evaluated TSS and mercury levels in Central Valley outflows to San Francisco Bay by collecting samples at X2. Figure 6.9 in Chapter 6 illustrates a typical location of X2. Board staff conducted monthly mercury and TSS sampling at X2 from March 2000 to September 2001 (Foe, 2003) and from April 2003 to September 2003 (Appendix L). Table 7.13 and Figures I.4a and I.4b in Appendix I summarize the available total mercury and TSS concentration data for X2. Total mercury concentrations at X2 averaged 18.1 ng/l and ranged from 3.9 ng/l to 49.2 ng/l. The TSS concentrations at X2 averaged 62 mg/l and ranged from 27 mg/l to 168 mg/l. Net daily Delta outflow was obtained from the Dayflow model (Appendix E). Total mercury and TSS concentrations at X2 were regressed against Delta outflow to determine whether either could be predicted from flow. Neither regression was significant. Therefore, average mercury and TSS concentrations were multiplied by average annual water volume for WY2000-2003, WY1984-2003 and WY1995-2005 to estimate annual loads (Table 7.14). These estimates only account for advective or riverine transport and do not incorporate dispersive or tidal flux. Annual average mercury loads to San Francisco Bay were

270, 379, and 691 kg/yr for WY2000-2003, WY1984-2003 and WY1995-2000, respectfully (Tables 7.12 and 7.14).

Four studies have measured mercury and sediment loads to San Francisco Bay from the Delta (Table 7.14). The results are surprisingly variable and range from 83 to 690 kg/yr for mercury. Some of the variation is undoubtedly due to the fact that different studies have measured export rates in different hydrologic years. However, three studies estimated annual average mercury export rates for WY1995-2000. The values range between 270 ±91 and 690 ±240 kg/yr (Table 7.14). The lower two rates (270 and 440 kg/yr) may be the more accurate for several reasons. First, both incorporate estimates of tidal dispersion in their load calculations. Tidal dispersion at Mallard Island reduces export rates as incoming tides have a greater sediment and mercury concentration than outgoing ones. This reduces the net export rate and likely provides a more accurate estimate. Second, both lower rates measured mercury at Mallard Island. In contrast, the TMDL measured sediment and mercury concentrations at X2. X2 is centered at Mallard Island but moves about 10 miles up and down the estuary depending on river outflow and tidal stage. X2 measurements are appropriate for predicting biotic exposure of water column organisms, such as pelagic fish, to methylmercury. This was the primary objective of the study. However, such measurements are undoubtedly less reliable than repeated water column measurements at Mallard Island for predicting mercury and sediment transport past the island. All present studies are deficient in that they did not measure export rates during high flow. High flow is when most of the mercury and sediment is in motion.

The Delta experienced high outflow during January and February of 2006. SFEI, Central Valley and San Francisco Bay Regional Board staff collaborated on a cooperative study of mercury and sediment transport at Mallard Island. A report should be available in 2008. It is recommended, until consensus is reached on 20-year export rates at Mallard Island, that compliance with the San Francisco mercury allocation to the Central Valley be determined by monitoring Delta inputs.

Table 7.13: Summary of Total Mercury and TSS Concentration Data for X2

	# of Samples [a]	Min. Conc.	Ave. Conc.	Median Conc.	Max. Conc.
TotHg (ng/l)	20	3.95	18.10	11.59	49.20
TSS (mg/l)	20	27.0	62.41	44.50	168.0

(a) Sampling at X2 took place between March 2000 and September 2003.

Table 7.14: Estimates of Delta Exports to San Francisco Bay

Study [a]	Sampling Location	Period	Average Water Year Hydrologic Index [b]	Average Annual Water Volume (M acre-feet) [c]	Average Annual TotHg Load ± 95% CI (kg)	Average Annual TSS Load ± 95% CI (kg)	TotHg:TSS (mg/kg)
Delta TMDL Program X2 Calculations	X2 [d]	WY2000-2003	7.3	12	270 ±93	930 ±283	0.29
		WY1984-2003	7.8	17	379 ±132	1,309 ±398	
		WY1995-2000	11.0	31	691 ±240	2,384 ±726	
Foe (2003)	X2	WY2001 [e]	5.8	7.2	122	473	0.26
S.F. Bay TotHg TMDL (2004)	Mallard Island	WY1995-2000	11.0	31	440 ±100	1,600 ±300	0.26 ±0.08
Leatherbarrow & others (2005) [f]	Mallard Island	WY1999-2003	7.8	18	97 ±33	524 ±166	0.19
		WY2000-2003	7.3	12	83 ±28	450 ±140	0.18
		WY1995-2000	11.0	31	270 ±91	1,600 ±510	0.17
		WY1995-2003	9.6	24	201 ±68	1,202 ±381	0.17

(a) Sources: this report; Leatherbarrow and others, 2005; Johnson and Looker, 2004; Foe (CALFED), 2003.

(b) DWR calculated a hydrologic index for the Sacramento Valley (DWR, 2006; see Appendix E). “Normal” hydrologic conditions for the Sacramento Valley are represented by an index value of 7.8, “wet” is ≥9.2, “dry” is between 5.4 and 6.5, and “critical dry” is ≤5.4.

(c) All average annual water volumes are from the Dayflow model results for Delta outflows to San Francisco Bay.

(d) The 95% confidence intervals (CI) were calculated using the method described in Appendix I.

(e) Foe’s 2003 CALFED study estimated monthly total mercury and TSS loads for March 2000 through September 2001, but did not include load estimates for November 2000. November total mercury and TSS loads for WY2001 were estimated by averaging the loads for October and December 2000.

(f) Leatherbarrow and others (2005) extrapolated total mercury loads from suspended sediment flux and suspended sediment mercury levels by adjusting for tidal dispersion and salinity, where for conductivity < 2 mS/cm, TotHg:TSS is 0.11 mg/kg, and conductivity > 2 mS/cm, TotHg:TSS is 0.29 mg/kg. Central Valley Water Board staff averaged the annual load estimates provided by Leatherbarrow and others (2005) for WY1995 through 2003 to estimate average annual loads for the periods that correspond to the San Francisco Bay mercury TMDL study period (WY1995-2000) and the Delta mercury TMDL WY2000-2003 study period. Volume-weighted TotHg:TSS ratios for each period were calculated by dividing the average annual mercury load (kg) by average annual TSS load (Mkg).

7.2.2 Exports South of Delta

Water diversions to the San Joaquin Valley and southern California account for 4 to 6% of mercury exports from the Delta and 6 to 8% of TSS exports (Table 7.12). Delta Mendota Canal (DMC) and State Water Project (SWP) exports were evaluated by collecting water samples from the DMC canal off Byron highway (County Road J4) and from the input canal to Bethany Reservoir, respectively. Bethany is the first lift station on the State Water Project canal system and is about one mile south of Clifton Court Forebay in the Delta (Figure 6.9).

Central Valley Water Board staff collected monthly total mercury and TSS samples from the DMC and SWP between March 2000 and September 2001 (Foe, 2003) and between April 2003 and 2004 (Appendix L). Table 7.15 and Figures I.4a and I.4b in Appendix I summarize the data. DMC and SWP exported water volumes were obtained from the Dayflow model (Appendix E). Total mercury and TSS concentrations were regressed against daily flow at both sites to determine whether concentrations could be predicted from flow. The regressions were not significant. Therefore, average mercury and TSS concentrations were multiplied by the WY2000-2003 and WY1984-2003 average annual water volume to estimate loads (Table 7.12).

Table 7.15: Summary of Total Mercury and TSS Concentration Data for Exports South of the Delta

Site	# of Samples [a]	Min. Conc.	Ave. Conc.	Median Conc.	Max. Conc.
Delta Mendota Canal					
TotHg (ng/l)	23	1.85	3.41	3.28	5.96
TSS (mg/l)	22	9.2	20.1	18.9	36.0
State Water Project					
TotHg (ng/l)	20	1.16	2.91	2.20	7.17
TSS (mg/l)	20	4.4	11.9	8.2	59.0

(a) Sampling of these exports took place between March 2000 and September 2003.

7.2.3 Dredging

Sediment is dredged from the Delta to maintain the design depth of ship channels and marinas. Dredge material is typically pumped to either disposal ponds on Delta islands or upland areas with monitored return-flow. Table 6.17 provides details on recent dredge projects in the Delta and Figure 6.9 shows their approximate location. The Sacramento and Stockton deep water channels have annual dredging programs; the locations dredged each year vary. Dredging occurs at other Delta locations when needed, when funds are available, or when special projects take place. Approximately 533,000 cubic yards of sediment are removed annually with about 199,000 cubic yards from the Sacramento Deep Water Ship Channel and about 270,000 cubic yards from the Stockton Deep Water Channel. Other minor dredging projects, mostly at marinas, remove an additional 64,000 cubic yards per year.

The amount of mercury removed annually by dredging was estimated by multiplying dredge volume at each project site by its average mercury concentration. Average mercury concentrations in the sediment for the project sites range from 0.04 to 0.41 mg/kg (dry weight). Two critical assumptions were made to calculate the total mercury removed from the Delta by dredging projects:

- Water content of the dredged material is 100% (50% water and 50% sediment by weight) (USACE, 2002); and
- There are about 570 kilograms of dry sediment per cubic yard of wet dredged material based on relative densities of water and sediment (Weast, 1981; Elert, 2002).

The calculations indicate that annual dredging in the Delta removes about 57 kg of mercury and 349 Mkg of sediment. This accounts for approximately 12 to 15% of all mercury exports and 19 to 25% of all sediment exports (Table 7.12). Board staff will continue to collect dredging data and evaluate the annual variability of the measurements.

7.2.4 Evasion

The loss of elemental mercury from water surfaces can be estimated on the basis of measured dissolved gaseous elemental mercury concentrations, atmospheric mercury concentrations, and estimated wind speeds (Conaway *et al.*, 2003). Conaway and others (2003) estimated summer and winter evaporation rates for San Francisco Bay. The Bay has a surface area of approximately 1.24 x 10^9 square meters (~306,400 acres) and is estimated to lose about 190 kg/yr of mercury to the atmosphere (Johnson and Looker, 2004). Similar estimates are not available for the Delta. However, an ongoing CALFED project (ERP-02-C06-B) is attempting to measure evasion in the Delta. The results should become available in 2008. To obtain a preliminary estimate of evasion in the Delta, it was assumed that the loss rate would be proportional to that of San Francisco Bay. The mercury lost from the Bay's surface (190 kg/year) was multiplied by the ratio of the water surface area of the Delta to that of the Bay (0.16). The result is an evasion rate of about 30 kg/yr or 6 to 8% of all mercury losses.

7.3 Total Mercury & Suspended Sediment Budgets

Delta mercury and suspended sediment assessments rely on a box model approach to approximate mass balances. Mass balances are useful because the difference between the sum of known inputs and exports is a measure of the uncertainty of the load estimates and can provide an indication of whether the Delta is depositional or erosional. The average annual water, mercury and TSS budgets for WY2000-2003 and WY1984-2003 are presented in Table 7.16.

The sum of water inputs and exports balance within 5%, indicating that all the major water sources and losses have been identified. In contrast, the mercury and TSS budgets do not balance and vary substantially depending on which estimates are used to characterize Delta outflows to San Francisco Bay. Table 7.16 incorporates the Delta TMDL Program's X2 calculations (Table 7.14), which results in mercury and TSS budgets that indicate that exports are greater than imports. This would imply that the Delta is erosional. However, this conclusion should be viewed with caution because the export rates used in the calculation are greater than those measured by others (Table 7.13) and may be biased high.[42] The Table 7.16 budget results are also in conflict with the conclusions of Wright and Schoellhamer (2005), who determined that about 65% of the sediment entering the Delta was deposited there. The mass balance calculations should be repeated once a better estimate of mercury and sediment exports at Mallard Island are determined.

[42] For example, if Leatherbarrow and others' 2005 load estimates of 83 kg/yr mercury and 450 Mkg/yr TSS are incorporated in the WY2000-2003 budget in Table 7.16, inputs would exceed exports, implying that the Delta is depositional.

Table 7.16: Water, Total Mercury and TSS Budgets for the Delta for WY2000-2003 and WY1984-2003.

	Water Volume (M acre-feet/yr)		Average Annual Load			
			WY2000-2003		WY1984-2003	
	WY2000-2003	WY1984-2003	TotHg (kg/yr)	TSS (Mkg/yr)	TotHg (kg/yr)	TSS (Mkg/yr)
Inputs	20.07	23.64	221 ±4	1,081 ±28	403 ±7	2,164 ±51
Exports	18.99	23.29	377 ±112	1,387 ±271	484 ±143	1,756 ±381
Inputs - Exports	**1.08**	**0.35**	**-156**	**-306**	**-81**	**408**
Exports ÷ Inputs	**95%**	**99%**	**170%**	**128%**	**120%**	**81%**

7.4 Evaluation of Suspended Sediment Mercury Concentrations & CTR Compliance

The evaluation of mercury contamination on suspended sediment particles for each Delta input and export site – in tandem with the source load analyses described in Sections 7.1 and 7.2 – is used to identify locations for possible remediation. The recommended total mercury control strategy described in Chapter 8 focuses on sources that have large mercury loadings and suspended sediment with high mercury concentrations, the premise being that it will be more cost effective to focus cleanup efforts on watersheds that export large amounts of highly contaminated sediment. In addition, the strategy incorporates source reductions needed to meet and maintain compliance with the CTR throughout the Delta.

7.4.1 Suspended Sediment Mercury Concentrations

Table 7.17 lists mercury to TSS ratios for Delta sources and export sites calculated using three different methods. The three approaches provide a range of particulate mercury contamination fluxing past a site. First, the ratios (in mg/kg) were estimated by dividing average annual mercury load (kg) by average annual TSS load (Mkg). This relationship is the preferred approach for Delta tributaries with statistically significant mercury and TSS relationships with flow because it provides a flow-weighted estimate. The ratio was also estimated from the slope of the regression between mercury and TSS using paired samples. This is the preferred approach for exports at Mallard Island as it is not biased by not having an accurate measure of the total export load. The least acceptable method is to take the median of the mercury to TSS ratios computed from individual paired samples. The median value tends to overemphasize low and moderate flows (the flows sampled most often) and not high flow events, which transport the majority of the suspended sediment and mercury. All three methods slightly overestimate particulate mercury (the focus of the San Francisco Bay sediment goal of 0.2 mg/kg) because none subtract the dissolved fraction from the total mercury concentration.

Table 7.17: Mercury to Suspended Sediment Ratios for Delta Inputs and Exports

	# of TotHg/TSS Paired Samples	Method A [a] TotHg Load ÷ TSS Load		Method B Linear Regression Slope for Paired TotHg/TSS [b]	Method C Median of TotHg/TSS Paired Sample Results
		WY2000-2003	WY1984-2003		
DELTA INPUTS					
Bear/Mosher Creeks	4	0.12		0.07	0.24
Calaveras River	4	0.25		0.17	0.41
French Camp Slough	4	0.70		0.63	0.30
Marsh Creek	7	0.49		0.12	0.19
Mokelumne River	20	0.37		0.37	0.42
Morrison Creek [c]	15	0.18		0.15	0.22
Prospect Slough (Yolo Bypass)	44	0.19	0.17	0.18	0.20
Sacramento River (Freeport)	134	0.21	0.21	0.17	0.24
San Joaquin River	29	0.13	0.13	0.13	0.14
Ulatis Creek	4	0.13		0.11	0.14
Urban Runoff [d]	128 (123)	0.31		0.18 (0.22)	0.35
DELTA EXPORTS					
Outflows to San Francisco Bay (X2)	20	0.29		0.30	0.28
State Water Project	19	0.24		0.18	0.29
Delta Mendota Canal	22	0.18		0.16	0.18
Dredging [e]	*8 projects*	0.19		- - -	0.03 to 0.41
TRIBUTARIES TO THE SACRAMENTO BASIN [Sacramento River + Yolo Bypass]					
American River	109	0.50	0.27	0.20	0.41
Cache Creek Settling Basin	21	0.39	0.45	0.48	0.36
Colusa Basin Drain	56	0.09		0.09	0.07
Feather River	60	0.29	0.31	0.26	0.33
Natomas East Main Drain (Arcade Ck.)	8	0.64		0.38	0.45
Putah Creek	29	0.45	0.55	0.26	0.30
Sacramento River above Colusa	47	0.12	0.12	0.12	0.11
Sutter Bypass (Sacramento Slough)	52	0.14		0.13	0.13

(a) The preferred method for each monitoring location is highlighted in gray. If total mercury concentrations and TSS concentrations both correlated well with daily flow at a given monitoring location, Method A was the preferred method for estimating suspended sediment mercury concentrations. If the available concentration data for a location were too variable and/or sparse to reliably estimate annual average suspended sediment concentrations, none of the values were highlighted. The WY1984-2003 period was evaluated only for Sacramento Basin tributaries because the other tributary loads are based on average concentrations, resulting in the same TotHg:TSS ratios for both periods.

(b) Regressions between total mercury and TSS concentrations are illustrated in Appendix I.

(c) Appendix I provides the data for each Morrison Creek sampling location.

(d) Urban runoff samples were collected at eleven locations. Methods B and C were performed between the urban runoff total mercury and TSS concentration data with and without five dramatically different sample TotHg:TSS ratios observed for Strong Ranch Slough.

(e) Sediment mercury concentrations in dredged material varied substantially across the Delta. The range of project-specific average concentrations was 0.02 to 0.77 mg/kg. The volume-weighted average mercury concentration of all the dredged material was approximately 0.19 mg/kg.

7.4.1.1 Mercury to TSS Ratios for Delta Outflows to San Francisco Bay

The San Francisco TMDL for mercury proposes a sediment objective of 0.2 mg/kg (Johnson and Looker, 2004). Mercury contamination on sediment (TotHg:TSS) in Delta outflow to San Francisco Bay averaged between 0.17 mg/kg and 0.30 mg/kg (Tables 7.14 and 7.17). The lower values are from estimates of mercury and suspended sediment loads at Mallard Island that attempt to better address tidal dispersion from Bay area. The higher values are based on measurements taken in mid channel at X2. The higher values may overestimate the degree of mercury contamination being exported from the Central Valley to San Francisco Bay. The major source of mercury and sediment to the Delta is from the Sacramento Basin. Suspended sediment ratios for the Sacramento River and Yolo Bypass range between 0.16 and 0.24 mg/kg of mercury (Table 7.17). These values are also consistent with bulk sediment concentrations in the Delta of 0.15 to 0.2 mg/kg determined by Slotton and others (2003) and Heim and others (2003). The results suggest that the contaminated sediment at X2 did not entirely originate from the Central Valley during the study period.

The X2 TotHg:TSS ratios of 0.28 to 0.30 mg/kg are similar to suspended sediment mercury concentrations of 0.33 mg/kg in San Pablo Bay (Schoellhamer, 1996) and bulk surficial sediment mercury concentrations in Suisun Bay of 0.3 to 0.35 ppm (Slotton *et al.*, 2003; Heim *et al.*, 2003). Hornberger and others (1999) report that the mercury concentration of sieved surficial sediment (<0.64 µm) in a core from Suisun Bay was 0.30 mg/kg; however, the concentration increased to 0.95 mg/kg at a depth of 30 cm. The mercury enriched zone persisted to a depth of about 80 cm before declining to a baseline concentration of 0.06 ±0.01 mg/kg. The increased mercury concentration at 30 cm was ascribed to deposition of mercury contaminated gold tailings. No current information is available on erosion rates in Suisun and Grizzly Bays but both embayments were eroding at the rate of 528 Mkg per year between 1942 and 1990 (Cappiella *et al.*, 2001). Therefore, a hypothesis is that the elevated mercury contamination on suspended sediment particles at X2 is the result of continuing erosion from Suisun Bay and possibly San Pablo Bay. Both embayments are within the legal jurisdiction of the San Francisco Bay Water Board and are part of its TMDL for mercury.

Urban runoff and almost all Delta inputs have mercury to TSS ratios greater than 0.2 mg/kg (Table 7.17). Exceptions are the San Joaquin River, Ulatis Creek, and Yolo Bypass. An evaluation of the tributary sources to the Sacramento River and Yolo Bypass indicates that all but the Sacramento River above Colusa, Sacramento Slough and Colusa Basin Drain have ratios greater than 0.2 mg/kg. A comparison of Table 7.5 and Table 7.17 indicates that several tributaries in the Sacramento Basin have high mercury to TSS ratios and large loads of mercury. Cache Creek and Feather River have high ratios and high average annual total mercury loads. This makes both attractive candidates for mercury control programs. The American River and Putah Creek also have high ratios but comparatively smaller mercury loads. In contrast, the Sacramento River above Colusa and Sacramento Slough (which receives most of its annual flows when upper Sacramento River flood waters are diverted to Sutter Bypass) have mercury to TSS ratios (0.12 and 0.13 mg/kg, respectively) comparable to background levels but high mercury loads. This is because both are transporting large amounts of sediment. The 2002 LWA report noted a similar pattern in its evaluation of median mercury to TSS ratios for the Sacramento Basin. Suspended sediment mercury concentrations between 0.03 and 0.19 mg/kg may result from a combination of erosion of background soils and atmospheric deposition from regional and global mercury sources. Therefore, the low mercury to TSS ratios for the upper Sacramento River watershed may indicate, unless site-specific hot spots are found, that very little total mercury could be removed by means other than erosion control.

7.4.2 Compliance with the USEPA's CTR

The USEPA's California Toxic Rule mercury criterion is 0.05 µg/L (50 ng/l) total recoverable mercury for freshwater sources of drinking water. The CTR criterion was developed to protect humans from exposure to mercury in drinking water and in contaminated fish. It is enforceable for all waters with a municipal and domestic water supply or aquatic beneficial use designation. This includes all subareas of the Delta. The CTR does not specify duration or frequency. As noted in Chapter 2, the Central Valley Water Board has previously employed a 30-day averaging interval with an allowable exceedance frequency of once every three years for protection of human health.

Mercury samples were not collected at a sufficiently high frequency to evaluate compliance with a 30-day average interval. Data therefore do not exist to show whether the CTR has actually been exceeded. To evaluate compliance with the CTR, regression analyses of flow and concentration were used to estimate 30-day running averages. As described in Sections 7.1.1.1 through 7.1.1.3, total mercury concentrations measured in instantaneous grab samples at Delta and Sacramento Basin tributary locations near flow gages were regressed against daily flow to determine if total mercury concentrations for days with no concentration data could be predicted. Figures 7.4 and 7.5 illustrate the regression-based 30-day running averages for locations with statistically significant ($P<0.01$) TotHg/flow correlations. Appendix I provides the TotHg/flow regressions upon which the 30-day averages are based. Table 7.18 provides a summary of the CTR compliance evaluation.

A waterway location was considered to be in compliance if its regression-based 30-day average total mercury exceeded 50 ng/l no more than once in any three-year period. Some locations had total mercury/flow regressions that were not statistically significant; also, some locations with concentration data were not near a flow gage. Such locations on larger waterways (e.g., Mokelumne River and San Joaquin River) were considered likely to be in compliance if none of the grab samples had mercury concentrations that exceeded 50 ng/l. Locations on small tributaries that typically experience short-duration, storm-related high flow events (e.g., French Camp Slough and Ulatis Creek) were considered likely to be in compliance if none of the water samples had mercury concentrations exceeding 50 ng/l, or if the exceedances occurred only during peak storm flows.

The evaluation of regression-based 30-day running average total mercury concentrations and available grab sample total mercury results indicates that all sampled locations within the Delta – except possibly Prospect Slough and Marsh Creek – are in compliance with the CTR criterion for total mercury. Although none of the grab samples collected from Marsh Creek near Highway 4 exceeded 50 ng/l total mercury, the regression-based 30-day running averages indicated that the CTR criterion might have been exceeded during one period. However, only about three years of flow data were available for the Marsh Creek location; therefore, compliance with the CTR criterion cannot be adequately determined with available data. Marsh Creek is already identified on the 303(d) List as impaired by mercury. The future mercury TMDL monitoring program for Marsh Creek will conduct another evaluation of CTR compliance as more data become available.

Evaluation of Yolo Bypass compliance with the CTR is complicated by the variety of watersheds that contribute water to it during varying hydrologic regimes. During low flow conditions, the Yolo Bypass receives flows from coastal mountain watersheds, particularly Cache Creek and Putah Creek, and other agricultural and native areas that drain directly to the bypass (Figure 7.1). During high flow conditions on the Sacramento River, excess flows from the upper Sacramento River, Sutter Bypass, Feather River, Colusa Basin, and American River watersheds may be routed down the Yolo Bypass at Fremont Weir, Sacramento Bypass and Knights Landing Ridge Cut. In a typical storm event, flows from the Cache Creek Settling Basin and other local sources reach the Yolo Bypass first, to be followed by lower concentration inputs from the Colusa Basin, Sacramento River and Feather River.

As indicated in Figure 7.4 and described in detail in Appendix E (Section E.2.2 and Figure E.3), the Yolo Bypass may not experience 30 days of continuous net outflow from Lisbon Weir upstream of Prospect Slough during dry years. In addition, storm data collected in 1995 indicate that total mercury concentrations in Prospect Slough (the primary outflow from the Bypass to the Delta) peak for a very short time. To evaluate conditions within the Bypass, the total mercury levels in tributary inputs to the Bypass were evaluated (Figure 7.5). The regression-based 30-day averages of predicted total mercury concentrations in the Sacramento River upstream of Colusa, Putah Creek and Feather River indicate that their flows are in compliance with the CTR criterion. However, the regression-based 30-day running average total mercury concentrations in Cache Creek Settling Basin outflows indicate that Cache Creek flows into the Yolo Bypass are not in compliance with the CTR criterion. This implies that when the Bypass is dominated by flows from Cache Creek, it may not be in compliance with the CTR criterion. Therefore, the Yolo Bypass area downstream of the Cache Creek Settling Basin probably does not meet the CTR criterion.

The Basin Plan Amendment for control of mercury in Cache Creek was adopted by the Central Valley Water Board in October 2005. As outlined in the Basin Plan Amendment report (Cooke and Morris, 2005), implementation actions would enable CTR compliance in outflows from Cache Creek. In order to meet the mercury loading allocation proposed for the Central Valley by San Francisco Water Board staff, the total mercury reduction strategy described in Chapter 8 assigns a 37% load reduction to mercury exports from the Feather River, American River and Putah Creek. In addition, these waterways are already identified on the 303(d) List as impaired by mercury. If future monitoring indicates that Cache Creek Settling Basin outflows to the Yolo Bypass do not comply with the CTR even after proposed total mercury reductions are achieved, and other reductions designed to accomplish safe fish tissue methylmercury levels in Cache Creek are achieved, additional reductions will be required.

Key points for the total mercury source analysis are listed after Figures 7.4 and 5 and Table 7.18.

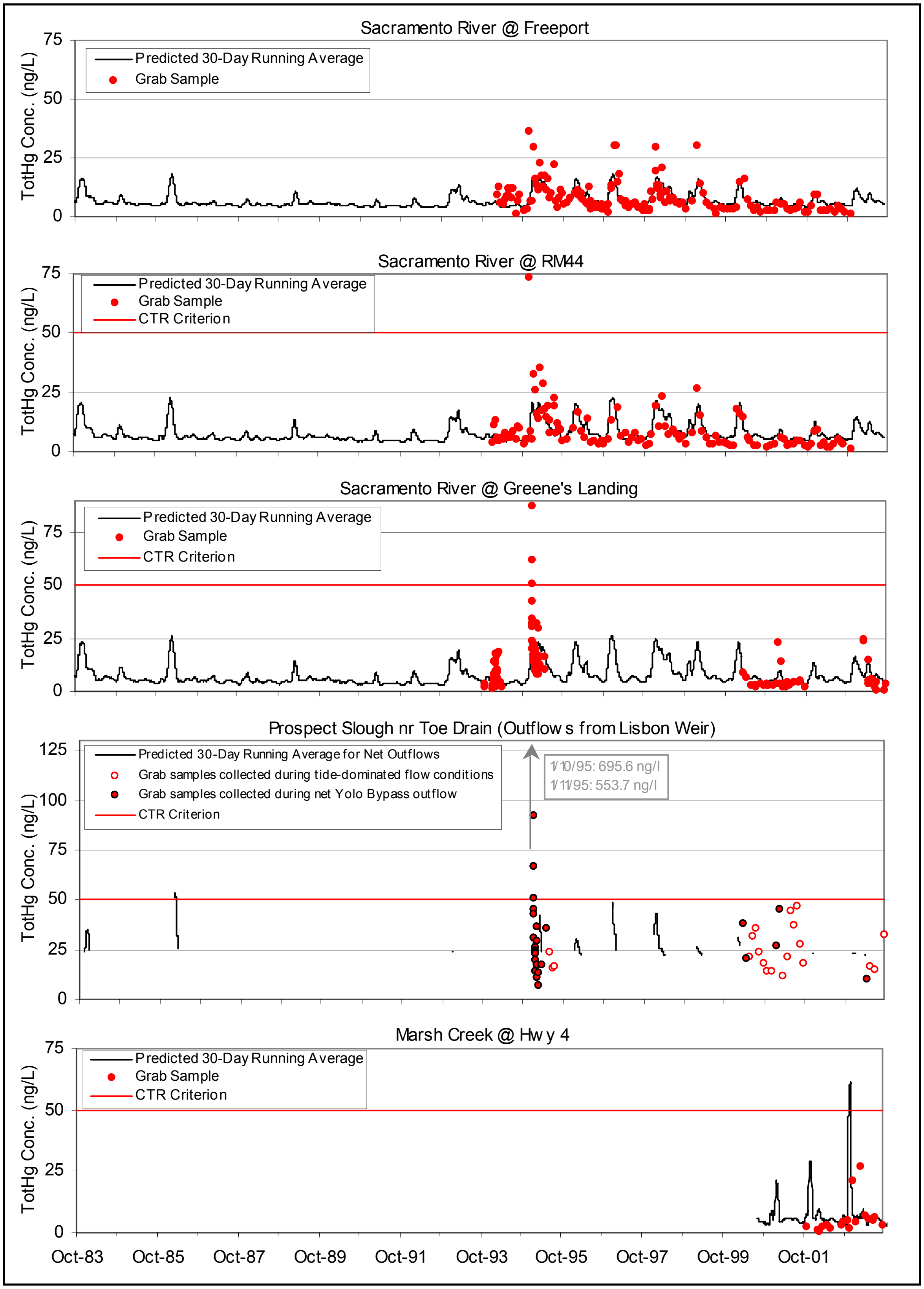

Figure 7.4: Grab Sample and Regression-Based 30-Day Running Average Total Mercury Concentrations for Delta Locations with Statistically Significant (P<0.05) Aqueous TotHg/Flow Correlations

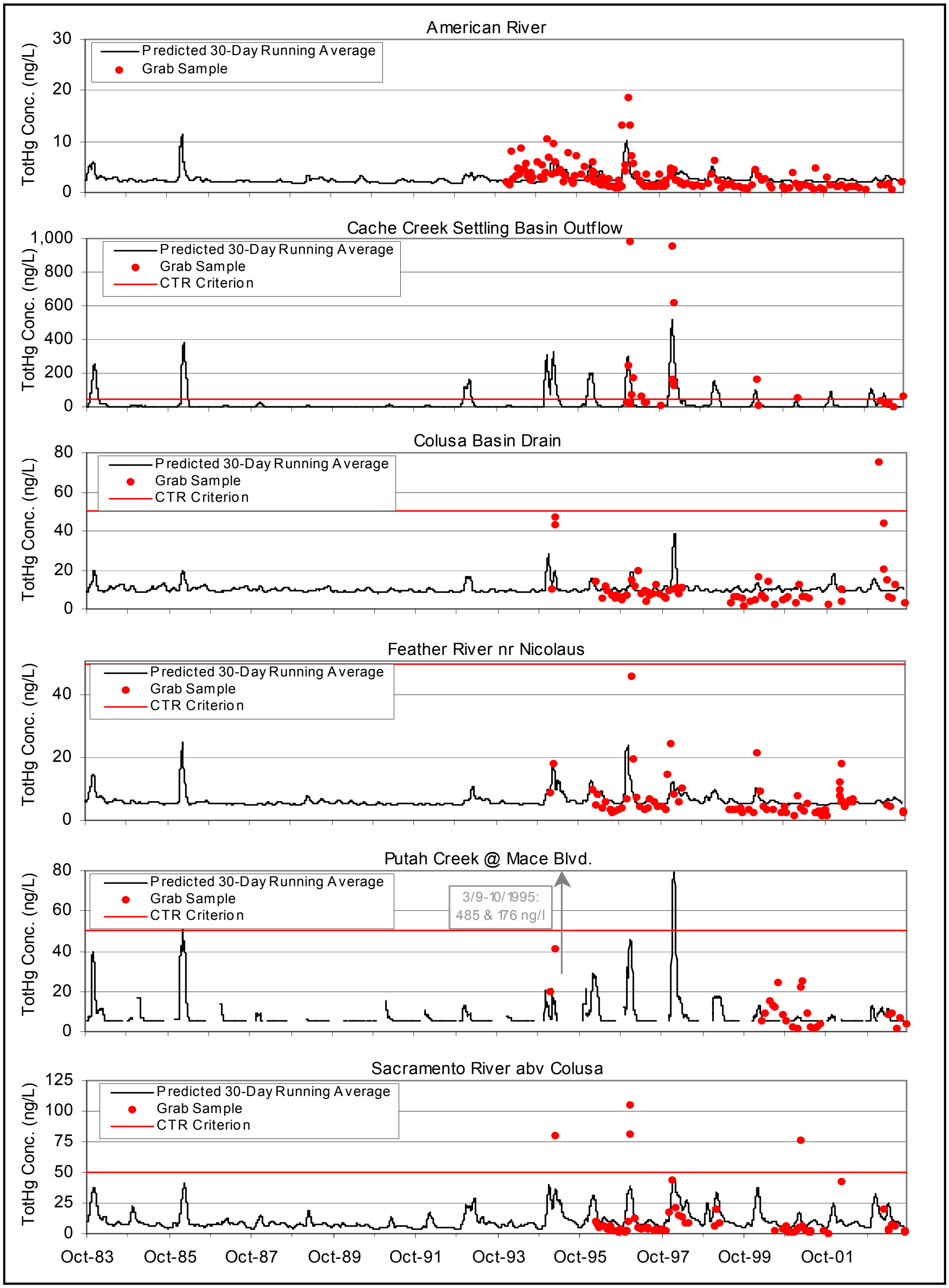

Figure 7.5: Grab Sample and Regression-Based 30-Day Running Average Total Mercury Concentrations for Sacramento Basin Tributary Locations with Statistically Significant (P<0.05) Aqueous TotHg/Flow Correlations

Table 7.18: Evaluation of CTR Compliance at Delta and Sacramento Basin Tributary Locations

Site	Is TotHg/Flow Regression Significant? [a]	Does Predicted 30-Day Average TotHg Concentration Ever Exceed the CTR (50 ng/l)? [a]	# of Grab Samples > 50 ng/l	Is the Site in Compliance with CTR?
DELTA LOCATIONS				
Bear/Mosher Creeks [b]	- - -	- - -	0	Likely Yes
Calaveras River @ RR u/s West Lane [b]	- - -	- - -	0	Likely Yes
Delta Mendota Canal	No	- - -	0	Likely Yes
French Camp Slough near Airport Way	- - -	- - -	1	Likely Yes
Marsh Creek @ Hwy 4	Yes	Once in 3 year record.	0	***Possibly Not***
Mokelumne River @ I-5	No	- - -	0	Likely Yes
Morrison Creek [c]	- - -	- - -	0	Likely Yes
Outflow to San Francisco Bay	No	- - -	0	Likely Yes
Prospect Slough (Yolo Bypass) [d]	Yes	Once [d].	5	***Possibly Not***
Sacramento River @ Freeport [e]	Yes	No.	0	Yes
Sacramento River @ Greene's Landing [e]	Yes	No.	4	Yes
Sacramento River @ RM44 [e]	Yes	No.	1	Yes
San Joaquin River @ Vernalis	No	- - -	0	Likely Yes
State Water Project	No	- - -	0	Likely Yes
Ulatis Creek near Main Prairie Rd	- - -	- - -	2	Likely Yes
SACRAMENTO BASIN TRIBUTARIES [f]				
American River @ Discovery Park	Yes	No.	0	Yes
Cache Creek d/s Settling Basin	Yes	In 11 of 20 years.	15	***No***
Colusa Basin Drain	Yes	No.	2	Yes
Feather River near Nicolaus	Yes	No.	0	Yes
Natomas East Main Drain [g]	- - -	- - -	1	Unknown
Putah Creek @ Mace Blvd. [h]	Yes	Twice, not within 3 years.	4	Likely Yes
Sacramento River above Colusa	Yes	No.	4	Yes
Sacramento Slough near Karnak [i]	No	- - -	0	Likely Yes

Table 7.18 Footnotes:

(a) Flow gage data were not available for most of the small tributary outflows to the Delta. All of the regressions for sampling locations near a flow gage were based on 20-year flow datasets except for Marsh Creek, for which only a 3-year dataset was available. Regressions were considered statistically significant for R^2 values with $P < 0.05$. Appendix I provides the regression plots.

(b) Only wet weather events were sampled on the Calaveras River and Bear and Mosher Creeks in Stockton. The one wet weather Mosher Creek sample result was combined with the Bear Creek dataset to evaluate compliance for both creeks.

(c) Concentration data collected at multiple sites on lower Morrison Creek were compiled to evaluate compliance.

(d) Sampling took place at Prospect Slough (export location of the Yolo Bypass) both when there were net outflows from tributaries to the Yolo Bypass and when there was no net outflow (i.e., the slough's water was dominated by tidal waters from the south). The regression analysis focuses only on the conditions when there was net outflow from the Yolo Bypass. Available flow information (Appendix E) indicates that during many years, the Yolo Bypass does not have a net outflow that lasts for 30 days or more.

(e) The Sacramento River sampling locations at Freeport and River Mile 44 (RM44) are upstream and downstream, respectively, of the outfall for the SRCSD WWTP. Greene's Landing is about nine miles downstream of the RM44 sampling location. Concentration data collected at all three sites were regressed against the flow data recorded at the Freeport gage, as no other gages are operational in this river reach. Appendix L provides the TotHg concentration data available for all three locations.

(f) Flows from the listed tributary watersheds may be diverted to the Yolo Bypass during high flow conditions via Knights Landing Ridge Cut, Fremont Weir and Sacramento Weir. The Coon Creek/Cross Canal watershed also contributes to the Sacramento River downstream of the Feather River but no aqueous TotHg data are available for its discharges.

(g) No concentration or flow data gage data were available for Natomas East Main Drain outflows. The SRWP, USGS and City of Roseville collected TotHg concentration data on Arcade Creek near Norwood and Del Paso Heights and Dry Creek. It was assumed that this dataset characterizes NEMD outflows.

(h) The predicted 30-day concentrations for Putah Creek are based on modeled flows (see Appendix E) estimated since the June 2006 draft TMDL Report. Although the regression between modeled flow and concentration is statistically significant ($P < 0.05$), there is greater uncertainty in the predicted 30-day concentrations. Two grab samples collected from a storm event in March 1995 and two grab samples from a storm event in February 2004 had TotHg concentrations greater than 50 ng/l: March 9 and 10, 1995: 485 and 176 ng/l; and February 18 and 25, 2004: 126 and 53 ng/l. Figure 7.5 does not illustrate grab samples collected after WY2003.

(i) Sacramento Slough near Karnak is the low flow channel for Sutter Bypass.

Key Points

- The primary sources of total mercury in the Delta include tributary inflows from upstream watersheds, atmospheric deposition, urban runoff, and municipal and industrial wastewater. Losses include flow to San Francisco Bay, water exports to southern California, removal of dredged sediments and evasion.
- The Sacramento Basin (Sacramento River + Yolo Bypass) contributed 83 to 87% of the mercury load to the Delta. Most of the material was transported during high flow.
- Present mercury exports rates to San Francisco Bay are unreliable. This precludes accurate calculations of erosion/deposition rates in the Delta and assessment of compliance with the proposed San Francisco Bay mercury allocation to the Central Valley at Mallard Island.
- The Cache Creek, Feather River, American River, and Putah Creek watersheds in the Sacramento Basin had both relatively large mercury loadings and high mercury to TSS ratios, making them attractive candidates for remediation.

8 METHYLMERCURY ALLOCATIONS, TOTAL MERCURY LIMITS & MARGIN OF SAFETY

This chapter presents recommended point and nonpoint methylmercury allocations and watershed total mercury limits for methyl and total mercury sources to the Delta. Reductions in ambient water methylmercury concentrations are required to reduce methylmercury concentrations in fish. Reductions in total mercury loads are needed to enable water and fish methylmercury reductions and to comply with the USEPA's CTR criterion for human protection and the San Francisco Bay mercury TMDL control program's total mercury allocation for the Central Valley. Section 8.1 describes the proposed methylmercury load and wasteload allocations for within-Delta and tributary inputs. Section 8.2 describes the proposed total mercury limits. Sections 8.3 and 8.4 describe the associated margin of safety and inter-annual and seasonal variability.

The methylmercury allocations and total mercury limits described in this chapter reflect the preferred implementation alternative described in Chapter 4 of the draft Basin Plan Amendment staff report and are designed to address the beneficial use impairment in all subareas of the Delta as well as in the San Francisco Bay. However, as described in the draft Basin Plan Amendment report, a number of alternatives are possible. The Central Valley Water Board will consider a variety of allocation strategies and implementation alternatives as part of the Basin Plan amendment process.

8.1 Methylmercury Load Allocations

Since the June 2006 draft TMDL and Basin Plan Amendment staff reports issued for scientific peer review, staff made the following changes to this section in response to comments made by the scientific peer reviewers and other agencies and stakeholders:

- Developed allocations only for dischargers within the legal Delta and the Yolo Bypass (including the portion north of the legal Delta), versus the legal Delta and all dischargers within 30 miles of the legal Delta boundary.
- Provided additional explanation of, and calculations for, the proposed methylmercury allocations to more directly address expected increases in source loading from predicted population growth and wetland restoration efforts and to acknowledge the efforts of those point sources whose effluent quality demonstrates good performance.
- Changed the methylmercury allocation strategy such that all point and nonpoint sources have load-based (versus load- and concentration-based) allocations to allow for a greater range of implementation options.
- Established percent allocations for tributary inputs based on a methylmercury concentration of 0.05 ng/l (rather than 0.06 ng/l, the proposed methylmercury goal for ambient water) to reserve assimilative capacity for methylmercury flux from sediments in open-water and wetland habitats and agricultural lands, and point source discharges within the Delta/Yolo Bypass with discharge methylmercury concentrations that exceed 0.06 ng/l.

- Re-calculated all allocations based on existing methylmercury discharge concentrations rounded to two decimal places and existing methylmercury loads rounded to two significant digits.
- Re-organized the text to avoid redundancy with allocation strategy explanations provided in Chapter 4 of the draft Basin Plan Amendment staff report and to improve clarity.

8.1.1 Definition of Assimilative Capacity

A water body's loading capacity (assimilative capacity) represents the maximum rate of loading of a pollutant that the water body can assimilate without violating water quality standards. A TMDL typically represents the sum of all individual allocations of the water body's assimilative capacity and must be less than or equal to the assimilative capacity. Allocations are divided among "wasteload allocations" for point sources and "load allocations" for nonpoint sources including natural background. The TMDL is the sum of these components:

Equation 8.1:

$$\text{TMDL} = \text{Wasteload Allocations} + \text{Load Allocations}$$

For the Delta methylmercury TMDL, wasteload allocations apply to discharges from existing and future NPDES-permitted WWTPs and MS4s within the Delta and Yolo Bypass. Load allocations apply to methylmercury flux from existing and future wetland and open-water sediments and agricultural lands and atmospheric deposition within the Delta and Yolo Bypass, as well as to tributary inputs to the Delta/Yolo Bypass. Natural background sources include atmospheric deposition, methylmercury flux from wetland and open-water sediments, and runoff from upland areas that existed prior to human-related pollution emissions such as mercury-contaminated sediment from historical mining activities in the tributary watersheds, mercury emissions from local and international industrial and municipal sources, and water management activities. Natural background sources are incorporated in the load allocations for wetlands, open water, and atmospheric deposition because data were not available to distinguish between natural background and nonpoint sources.

A TMDL need not be stated as a daily load (Code of Federal Regulations, Title 40, §130.2[i]). Other measures are allowed if appropriate. The methylmercury allocations proposed in Table 8.4 at the end of Section 8.1.3 are expressed in terms of average annual loads because the adverse effects of mercury occur through long-term bioaccumulation. The allocations are intended to represent annual averages and account for both seasonal and long-term variability. The annual load and wasteload allocations can be expressed in daily terms by simply dividing each allocation by 365.[43] However, to best attain and maintain the proposed fish tissue objectives, staff recommends that the allocations be implemented as average annual loads.

Methylmercury allocations were made in terms of the existing assimilative capacity of each of the different Delta subareas. A methylmercury TMDL must be developed for each Delta subarea because the sources and percent reductions needed to meet the proposed

[43] In its November 2006 memorandum concerning appropriate time increments for TMDLs, the USEPA recommended that States provide written documentation regarding how the TMDL allocations can be expressed in daily terms (USEPA, 2006).

implementation goal are different in each subarea. The linkage analysis (Chapter 5) described the calculation of an implementation goal for methylmercury in ambient water that is linked to the fish tissue methylmercury targets. The recommended implementation goal is an annual average concentration of 0.06 ng/l methylmercury in unfiltered water. This goal describes the assimilative capacity of Delta waters in terms of concentration (Section 5.2). Central Valley Water Board staff anticipates that as the average concentration of methylmercury in each Delta subarea decreases to the safe aqueous goal, then the targets for fish tissue will be attained. To determine necessary reductions, the existing average aqueous methylmercury levels in each Delta subarea were compared to the methylmercury goal (Table 8.1).

The amount of reduction needed in each subarea is expressed as a percent of the existing concentration. As noted in the linkage analysis, the aqueous methylmercury goal was developed using water data for March to October 2000 because this was the only period for which there was overlap between water data and the lifespan of the fish. Table 8.1 compares the proposed goal to average methylmercury concentrations for March to October 2000 (Scenario A) and for March 2000 to April 2004 (Scenario B). Scenario B is based on a much larger dataset and includes values for all seasons. However, the percent reductions are similar for both scenarios and range from 0 to 80% for the different subareas. Therefore, staff recommends the use of the proposed reductions listed in Scenario B for the calculation of assimilative capacity.

The assimilative capacity of each subarea (Table 8.2) was determined using the proposed reductions listed in Scenario B in Table 8.1 (except for the Central and West Delta subareas, as discussed in the next paragraphs), the sum of existing annual methylmercury inputs from identified sources (see Table 8.4 at the end of Section 8.1.3) and the following equation:

Equation 8.2: *(using the Sacramento subarea as an example)*

$$\begin{aligned}\begin{array}{c}\text{Assimilative}\\ \text{Capacity (g/yr)}\end{array} &= \begin{array}{c}\text{Existing MeHg}\\ \text{Inputs (g/yr)}\end{array} - \left[\begin{array}{c}\text{\% Reduction Needed to}\\ \text{Meet Proposed Goal}\end{array} * \begin{array}{c}\text{Existing MeHg}\\ \text{Inputs (g/yr)}\end{array}\right]\\ &= 2{,}418\text{ g/yr} - (44\% * 2{,}418\text{ g/yr})\\ &= 1{,}354\text{ g/yr}\end{aligned}$$

The subareas on the eastern boundary of the Delta require substantial reductions in fish and aqueous methylmercury levels. In contrast, ambient methylmercury concentrations in the Central and West Delta subareas equal or approach the proposed aqueous methylmercury goal of 0.06 ng/l, resulting in the need for little-to-no reductions in methylmercury inputs to these subareas. Because water quality in the Central and West Delta subareas is dominated by inflows from upstream Delta subareas that require reductions ranging from 44 to 80%, Central and West Delta fish tissue and ambient water methylmercury levels are expected to decrease when actions are implemented to reduce up-basin water methylmercury levels. In addition, the primary within-subarea source of methylmercury in the Central and West Delta subarea is flux from open water habitat sediments (Table 8.4). Therefore, staff recommends that no reduction be required for point and nonpoint source methylmercury discharges within the Central and West Delta subareas. Section 8.1.2 describes an allocation strategy that ensures that fish and water methylmercury concentrations in these subareas remain in compliance with the proposed fish tissue objectives and methylmercury goal for water.

The following two sections describe the strategy and calculations used to determine specific allocations for point and nonpoint sources listed in Table 8.4 for each of the subareas.

Table 8.1: Aqueous Methylmercury Reductions Needed to Meet the Proposed Methylmercury Goal of 0.06 ng/l. [(a)]

	Delta Subarea						
	Central Delta	Marsh Creek	Mokelumne River	Sacramento River	San Joaquin River	West Delta	Yolo Bypass
A. Scenario Based on March to October 2000 Aqueous MeHg Data [(b)]							
Average Aqueous MeHg Concentration (ng/l)	0.055	0.224	0.140	0.120	0.147	0.087	0.305
Percent Reduction Needed to Meet the Proposed MeHg Goal	0%	73%	57%	50%	59%	31%	80%
B. Scenario Based on March 2000 to April 2004 Aqueous MeHg Data [(b)]							
Average Annual Aqueous MeHg Concentration (ng/l)	0.060	0.224	0.166	0.108	0.160	0.083	0.273
Percent Reduction Needed to Meet the Proposed MeHg Goal	0%	73%	64%	44%	63%	28%	78%

(a) The amount of reduction needed in each subarea is expressed as a percent of the existing methylmercury concentration. For example, the percent reduction needed for the Marsh Creek subarea Scenario A is calculated by: (0.244 - 0.06) / 0.244 = 73%. The average March to October 2000 methylmercury concentration for the Central Delta is below the proposed implementation goal of 0.06 ng/l. As a result, Scenario A calculations for the Central Delta result in negative numbers: A(1): (0.055 - 0.06)/0.055 = -9%. No reduction is needed under Scenario A or B for Central Delta ambient methylmercury.

(b) Average concentrations are based on unfiltered MeHg concentration data collected at the following locations: Delta Mendota Canal and State Water Project (Central Delta); Marsh Creek at Highway 4; Mokelumne River near I-5; Sacramento River at Freeport, RM44 and Greene's Landing; San Joaquin River near Vernalis; outflow to San Francisco Bay measured at X2, usually near Mallard Island (West Delta); and Prospect Slough near Toe Drain (Yolo Bypass). The values for the Central Delta, Mokelumne River, Sacramento River, San Joaquin and West Delta subareas are described in Section 5.1 and Table 5.1 in Chapter 5 and are based on monthly average concentrations so that the average concentrations for each study period are not influenced by the unequal number of samples collected in each month. The Yolo Bypass average concentrations also are based on monthly average concentrations. The sampling frequency on Marsh Creek was inadequate to develop averages for each study period, much less to pool data by month; therefore, the average of all available concentration data was used in both scenarios. The Yolo Bypass and Marsh Creek data are described in Chapter 6, Section 6.2.1 and Table 6.3. It was assumed that the sampling locations are representative of the subareas in which they occur.

Table 8.2: Assimilative Capacity Calculations for Each Delta Subarea.

Delta Subarea	Existing Average Annual MeHg Conc. [(a)] (ng/l)	% Reduction Needed to Achieve Proposed Goal of 0.06 ng/l [(a)]	Existing Annual MeHg Load from Identified Sources [(b)] (g/yr)	Assimilative Capacity (g/yr)
Central Delta	0.060	0%	668	668
Marsh Creek	0.224	73%	6.1	1.6
Mokelumne River	0.166	64%	146	53
Sacramento River	0.108	44%	2,474	1,385
San Joaquin River	0.160	63%	528	195
West Delta	0.083	0%	330	330
Yolo Bypass [North & South]	0.273	78%	1,069	235

(a) No percent reductions are proposed for the Central and West Delta subareas because their fish tissue and aqueous methylmercury levels either currently achieve or are expected to achieve safe levels when actions are implemented to reduce upstream aqueous methylmercury levels. Proposed reductions for other subareas are from Table 8.1 Scenario B.

(b) "Existing Annual MeHg Load" represents the sum of all identified inputs to each subarea (Chapter 6 and Table 8.4).

8.1.2 Allocation Strategy

Table 8.4 at the end of Section 8.1.3 lists wasteload and load allocations for each point and nonpoint methylmercury input by subarea and reflects the preferred implementation alternative and resulting allocation strategy described in Chapter 4 of the draft Basin Plan Amendment staff report. This section summarizes the preferred allocation strategy developed in the draft Basin Plan Amendment staff report. Section 8.1.3 describes the equations used to calculate the individual allocations.

The available science is adequate to establish individual allocations for point sources in the Delta/Yolo Bypass and tributary inputs to the Delta/Yolo Bypass, and general (subarea) methylmercury allocations for nonpoint sources within the Delta/Yolo Bypass. The preferred allocation strategy specifies the following:

- Atmospheric deposition and discharges from urban areas outside of MS4 service areas[44] in all Delta subareas have load allocations set at their existing average annual methylmercury loads.
- All point and nonpoint sources in the Central and West Delta subareas have wasteload and load allocations set at their existing average annual methylmercury loads to ensure that compliance with the fish tissue objectives is maintained.
- Methylmercury flux from sediments in open-water habitats in all Delta subareas have load allocations set at their existing average annual methylmercury loads, except where open-water methylmercury production must be reduced to achieve the proposed fish tissue objectives (e.g., the Yolo Bypass and Marsh Creek subareas).
- Wasteload and load allocations integrate expected expansions to existing sources and new sources.

[44] As described in Chapter 4 of the draft Basin Plan Amendment staff report, if such urban communities expand significantly, or are found to be significant contributors of methylmercury or other pollutants, they could be designated Phase II MS4 dischargers and required to develop and implement sediment and/or mercury control plans like those proposed for existing Phase II dischargers.

- Waste load allocations acknowledge the efforts of those point sources whose effluent quality demonstrates good performance, and require improvement by other dischargers.

Anticipated population growth, regional water management changes, and wetland restoration efforts could result in increases in methylmercury loading to the Delta. For example, increasing populations will result in increasing total mercury and methylmercury discharges from municipal WWTPs and urban runoff. The California Department of Finance predicts that populations in the Delta/Yolo Bypass counties[45] will increase 76% to 213% by 2050 (CDOF, 2007), with an average increase of about 120%. (For more discussion on potential regional changes, see Section 8.4.3, "Regional and Global Change".)

The allocations for each existing source apply to the sum of its existing discharge and any expansion to its discharge in the future. The recommended open-water and wetland methylmercury allocations apply to all wetlands and open-water habitat acreage in each Delta subarea, including current wetlands and future wetland restoration projects. MS4 allocations apply to all urban acreage within MS4 service areas within each Delta subarea and similarly address loading from current and future urban areas within the MS4 service areas.

Staff assumed that, in general, NPDES-permitted WWTP discharges throughout the Delta/Yolo Bypass would increase by 120%. Staff assumed that half of that growth will be addressed by expansions to existing facilities in each Delta subarea, and that the remaining half will be serviced by new facilities in each subarea. Table 8.3 illustrates current WWTP effluent volumes discharged to each Delta subarea, the amount of discharge volume increase expected in each subarea, and the discharge volume that staff assumed will be addressed by existing and new facilities.

Results from methylmercury monitoring by NPDES facilities in the Delta and upstream tributary watersheds indicate that many facilities have average effluent methylmercury levels that approach or are less than the proposed implementation goal for unfiltered methylmercury in Delta waters (0.06 ng/l), while other facilities have much higher methylmercury levels (see Chapter 6 and Appendix G in the TMDL Report and Bosworth *et al*., 2008). This indicates that some discharges, though they contribute methylmercury loading to the Delta, may act as dilution because of their low methylmercury concentrations.

Staff recommends that source discharges with average methylmercury concentrations below the proposed aqueous methylmercury goal of 0.06 ng/l be considered dilution and assigned a wasteload allocation based on their existing discharge methylmercury concentration. There are five NPDES-permitted discharges that have methylmercury concentrations less than 0.06 ng/l: Brentwood WWTP, Deuel Vocational Institute WWTP, Oakwood Lake Subdivision Mining Reclamation, West Sacramento WWTP, and Woodland WWTP. The "Concentration Used to Calculate Allocation" in Table 8.4 for these sources was set at the existing discharge methylmercury concentration for each of these dischargers.

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45 The CDOF predicts the following population increases by 2050: Contra Costa County - 89%, Sacramento County - 76%, San Joaquin County - 213%, Solano County - 105%, and Yolo County - 93% (CDOF, 2007).

Conceptually, there is no need to limit the loading from sources that act as dilution, given the overall extent of impairment throughout the Delta. However, to enable the calculation of allocations required for other sources, load-based allocations must be calculated even for those sources that act as dilution. Staff assumed that the four municipal WWTPs with discharges less than 0.06 ng/l would increase their discharge volume by 60% to account for future population growth. Staff calculated their methylmercury wasteload allocations shown in Table 8.4 by multiplying their existing average effluent methylmercury concentrations by their current discharge volumes (shown in Table 8.3) multiplied by 160%. Staff also calculated "Unassigned WWTP allocations" in Table 8.4 for each subarea to address new WWTP discharges. Staff assumed that new WWTPs would be designed to discharge effluent with methylmercury concentrations equal to or less than 0.06 ng/l, and calculated the "Unassigned WWTP allocations" by multiplying the predicted volumes shown in Table 8.3a by 0.06 ng/l methylmercury.

To calculate allocations for WWTPs with effluent methylmercury concentrations greater than 0.06 ng/l, staff used the existing effluent volumes rather than multiply the existing volumes by 160%. Although these facilities may need to increase their discharged effluent volumes in response to population growth in their service areas, increased effluent volumes at their existing effluent concentrations, if allowed, would worsen the methylmercury impairment. Conceptually, discharge volume from a WWTP that has an average effluent methylmercury concentration greater than 0.06 ng/L could be allowed to increase so long as its methylmercury load does not increase. [46]

This approach is consistent with State Water Board Resolution No. 2005-0060,[47] which required the San Francisco Bay Water Board to incorporate provisions that acknowledge the efforts of those point sources whose effluent quality demonstrates good performance, and require improvement by other dischargers, when establishing waste load allocations.

To calculate load allocations for tributary inputs to Delta subareas that require methylmercury source reductions, staff recommends that the tributary inputs be assigned percent allocations based on a methylmercury concentration of 0.05 ng/l (rather than 0.06 ng/l, the proposed methylmercury goal for ambient water). Such an allocation strategy would ensure that assimilative capacity is reserved for methylmercury flux from sediments in open-water and wetland habitats, and agricultural and point source discharges within the Delta/Yolo Bypass with discharge methylmercury concentrations that exceed 0.06 ng/l.

[46] Discharge volume from a WWTP that has average effluent methylmercury concentrations greater than 0.06 ng/l could be allowed to increase so long as its load does not increase above its wasteload allocation. For example, an increase in volume would necessitate a decrease in methylmercury concentration to maintain the load allocation so that the increased volume does not cause an increase in receiving water methylmercury concentration. If an offset program is developed, another option could be for such a WWTP to compensate for increases in its load by completing offset projects upstream.

[47] On September 7, 2005, the State Water Board adopted Resolution No. 2005-0060 ("Remand Order") remanding the San Francisco Bay Water Board's San Francisco Bay Mercury TMDL Amendment with requirements for specific revisions to the TMDL and associated implementation plan.

Table 8.3a: Total Existing Municipal WWTP Effluent Volume Discharged to Each Delta Subarea, Predicted Increases Due to Population Growth, and Volumes and Methylmercury Loads Predicted to Be Discharged by New WWTPs.

Subarea	**Existing Effluent Volume** (mgd) [(a)]	**Predicted Increase** (mgd) [(b)]	**Effluent Volume Predicted to Be Discharged by New WWTPs** (mgd) [(c)]	**Effluent MeHg Load Predicted to Be Discharged by New WWTPs** (g/yr) [(d)]
Central Delta	6.1	7.3	3.7	0.31
Marsh Creek	3.1	3.7	1.9	0.16
Sacramento River	170	204	102	8.5
San Joaquin River	43	52	26	2.2
West Delta	0 [(e)]	6.9 [(e)]	6.9 [(e)]	0.57
Yolo Bypass	8.5	10.2	5.1	0.42

(a) "Existing Effluent Volume" is the sum of effluent volumes discharged by municipal WWTPs in each Delta subarea.

(b) Staff assumed that, in general, NPDES-permitted WWTP discharges throughout Delta/Yolo Bypass would increase by 120% in response to predicted population growth in the region.

(c) Staff assumed that half of the predicted 120% population growth would be addressed by expansions to existing facilities in each Delta subarea, and that the remaining half would be serviced by new facilities in each subarea. Staff predicted discharge volumes to be serviced by new WWTPs by multiplying the "Existing Effluent Volume" discharged to each subarea by 0.6.

(d) New WWTPs' discharge methylmercury loads were calculated by multiplying the predicted effluent volumes by 0.06 ng/l methylmercury.

(e) There are no WWTPs currently discharging in the West Delta subarea. However, the Ironhouse Sanitary District has submitted a Report of Waste Discharge, dated 11 June 2007, and applied for a NPDES permit authorization to discharge up to 4.3 mgd of treated wastewater from the Ironhouse Sanitary District WWTP to the San Joaquin River within the West Delta subarea. The WWTP will likely begin discharging to the San Joaquin River sometime in 2009. Staff calculated the "Predicted Increase" and "Effluent Volume Predicted to Be Discharged by New WWTPs" for the West Delta subarea by multiplying 4.3 mgd by 0.6 and adding the result (2.6 mgd) to 4.3 mgd, for a total of 6.9 mgd.

Table 8.3b: Predicted Effluent Volumes Used to Calculate Corresponding Methylmercury Loads for Municipal WWTPs that Currently Discharge Effluent with Average Methylmercury Concentrations Less than 0.06 ng/l.

Permittee [(a)]	**NPDES Permit No.**	**Existing Effluent Volume** (mgd)	**Predicted Effluent Volume Used To Calculate MeHg Loads for Allocations in Table 8.4** [(a)] (mgd)
Brentwood WWTP	CA0082660	3.1	5.0
West Sacramento WWTP	CA0079171	5.6	9.0
Deuel Vocational Inst. WWTP	CA0078093	0.47	0.75
Woodland WWTP	CA0077950	6.05	9.7

(a) Staff assumed that, in general, NPDES-permitted WWTP discharges throughout Delta/Yolo Bypass would increase by 120% in response to predicted population growth in the region. Staff assumed that half of the population growth would be addressed by expansions to existing facilities in each Delta subarea, and that the remaining half would be serviced by new facilities in each subarea. Discharges from WWTPs with effluent methylmercury concentrations less than 0.06 ng/l act as dilution. Staff recommends that these facilities be assigned allocations calculated using their existing effluent methylmercury concentrations. To determine loads for use in Table 8.4, discharge volumes for these WWTPs were multiplied by 160% to allow for volume and load increases due to predicted population growth.

8.1.3 Percent Allocation Calculations

As described in the previous section, the following sources have allocations set equal to 100% of their existing methylmercury loads: atmospheric deposition, discharges from urban areas outside of MS4 service areas, methylmercury flux from open-water habitat sediments (except in the Yolo Bypass and Marsh Creek subareas), and all point and nonpoint sources in the Central and West Delta subareas. In addition, WWTPs with effluent concentrations less than the proposed methylmercury goal for ambient water have wasteload allocations set equal to 160% of their existing loads.

As noted in Section 6.2.3, two of the facilities in the Delta are power or heating/cooling facilities that use ambient water for cooling water, Mirant Delta LLC Contra Costa Power Plant and the State of California Heating/Cooling Plant. Methylmercury loads and concentrations in heating/cooling and power facility discharges vary with intake water conditions; the facilities do not appear to act as a source of methylmercury to the Delta. Staff recommends that these facilities have concentration-based allocations equal to 100% of their intake methylmercury concentrations, such that their discharge allocations equal the detected methylmercury concentration found in their intake water. Outflows from these facilities were not incorporated in the allocation calculations for other sources and are not listed in Table 8.4. GWF Power Systems (CA0082309), in the West Delta subarea, acquires its intake water from sources other than ambient surface water and therefore was incorporated in the allocation calculations. GWF effluent methylmercury concentrations are less than the analytical method detection limit (0.03 ng/l; see Table 6.5 in Chapter 6). As a result, staff recommends that its allocation be equal to an annual load of 0.0052 g/yr, calculated by using the methylmercury method detection limit (0.03 ng/l) and GWF's design flow (0.125 mgd) to accommodate potential growth.

Discharge methylmercury data were not available for the Metropolitan Stevedore Company (CA0084174), a marine bulk commodity terminal on leased land at the Port of Stockton in the Central Delta subarea. Staff recommends that a methylmercury wasteload allocation for non-storm water discharges from the Metropolitan Stevedore Company be established in its NPDES permit once it completes at least three sampling events for methylmercury in its discharges. Its wasteload allocation will be a component of the "Unassigned WWTP Allocation" for the Central Delta subarea.

The following equation was used to determine the percent allocations for all other point and nonpoint sources needed to achieve the assimilative capacity in each Delta subarea:

Equation 8.3: *(using the San Joaquin subarea as an example)*

Percent Allocation =

$$= \frac{\text{Assim. Cap.} - \text{Sum (Allocations for Atm. dep., Open water, Nonpt urban, \& Sources w/ Ave. MeHg Conc.} \leq 0.06 \text{ ng/l)}}{\text{All existing loads} - \text{Sum (Existing loads for Atm. dep., Open water, Nonpt urban, \& Sources w/ Ave. MeHg Conc.} \leq 0.06 \text{ ng/l)}}$$

$$= \frac{195 \text{ g/yr} - (2.7 \text{ g/yr} + 48 \text{ g/yr} + 0.0022 \text{ g/yr} + 0.021 \text{ g/yr} + 0.38 \text{ g/yr} + 110 \text{ g/yr} + 3.9 \text{ g/yr} + 2.2 \text{ g/yr})^{\star}}{528 \text{ g/yr} - (2.7 \text{ g/yr} + 48 \text{ g/yr} + 0.0022 \text{ g/yr} + 0.013 \text{ g/yr} + 0.38 \text{ g/yr} + 356 \text{ g/yr} + 11 \text{ g/yr})}$$

$$= 25\%$$

⋆ Explanation: *As shown in Table 8.4e, allocated methylmercury loads for atmospheric deposition, open water, and nonpoint urban runoff were set at existing levels. Deuel Vocational Institute WWTP* *and Oakwood Lake Subdivision Mining Reclamation have average discharge methylmercury concentrations less than 0.06 ng/l, and existing annual loads of 0.013 g/yr and 0.38 g/yr, respectively. Both are assigned allocations based on their existing methylmercury concentrations. The Deuel Vocational Institute WWTP's corresponding load of 0.021 g/yr incorporates a percent allocation of 160%. The San Joaquin River and French Camp Slough each have a "MeHg Concentration Used to Calculate Allocation" set at 0.05 ng/l to reserve assimilative capacity for discharges within the San Joaquin subarea, and have annual average loads of 356 and 11 g/yr, percent reductions of 31% and 35%, and allocated loads of 110 ng/l and 3.9 ng/l, respectively. A load of 2.2 g/yr was reserved for new municipal WWTP discharges expected to service predicted population growth, which was based on a methylmercury concentration of 0.06 ng/l and discharge volume equal to 60% of existing WWTP discharges in the subarea (see Table 8.3).*

The percent allocations were applied to every point source discharge methylmercury concentration and load – except those with pre-determined allocations – within each subarea to calculate corresponding wasteload allocations using Equations 8.4 and 8.5. Methylmercury inputs from agricultural lands, wetlands, and open-water habitat are based on methylmercury loads produced *in situ* and therefore do not have corresponding concentrations. As a result, the percent allocations were applied to such nonpoint source loads within each subarea to calculate corresponding load allocations using only Equation 8.5.

Equation 8.4:
(using City of Stockton WWTP in the San Joaquin subarea as an example)

MeHg Concentration Used to Calculate Allocation (ng/l) =

= % Allocation * Existing average annual effluent MeHg conc.
= 25% * 0.94 ng/l
= 0.24 ng/l

Equation 8.5:

MeHg Wasteload Allocation (g/yr) =

= % Allocation * Existing average annual effluent MeHg load
= 25% * 36 g/yr
= 9.0 g/yr

Sometimes Equation 8.4 resulted in an average methylmercury concentration less than 0.06 ng/l. The preferred allocation strategy described in the draft Basin Plan Amendment staff report entails that no discharger (e.g., WWTPs and MS4s) be required to reduce its discharge average methylmercury concentration to less than 0.06 ng/l. If Equation 8.4 resulted in a value less than 0.06 ng/l for a particular point source discharge, the "Concentration Used to Calculate Allocation" was set at 0.06 ng/l and the allocation percent and equivalent load were calculated using the following equations:

Equation 8.6a: *(using the City of Tracy WWTP in the San Joaquin subarea as an example)*

% Allocation = Proposed implementation goal ÷ Existing average annual effluent MeHg Conc.
= 0.06 ng/l ÷ 0.14 ng/l
= 43%

Equation 8.6b:

$$
\begin{aligned}
\text{Equivalent MeHg Load} &= \text{\% Allocation} \;*\; \text{Existing Annual MeHg Load} \\
&= 43\% \;*\; 1.8 \text{ g/yr} \\
&= 0.77 \text{ g/yr}
\end{aligned}
$$

The ultimate purpose of this iterative set of calculations is to ensure that the sum of all methylmercury inputs to each Delta subarea does not exceed the assimilative capacity so that the proposed implementation goal for ambient water and proposed fish tissue mercury targets can be achieved in each subarea.

"Existing annual MeHg loads" for MS4 discharges and nonpoint sources in Table 8.4 represent the loads estimated for WY2000-2003, a relatively dry period. Loads discharged by these sources are expected to fluctuate with rainfall and river flow conditions and other environmental factors. Load estimates will be re-evaluated in subsequent phases of the TMDL implementation program as more data become available. As described in Chapter 4 of the draft Basin Plan Amendment staff report, staff recommends that responsible parties for point and nonpoint methylmercury discharges conduct collaborative source characterization and control studies during the next six or so years. To the extent that the efforts to develop methylmercury controls are effective, and/or further scientific information has been collected, the Central Valley Water Board may consider amendments to the Basin Plan to update the methylmercury allocations and implementation plan after the studies are completed.

More than 30% of the methylmercury in the Delta/Yolo Bypass is produced locally in sediment (Table 6.2). Methylmercury production is a positive linear function of the inorganic mercury content of sediment (Chapter 3). This TMDL requires a 110-kg/yr reduction in total mercury from upstream watersheds with mercury sediment concentrations greater than 0.2 mg/kg and large mercury loads (next section). This represents about a 31% decrease in the 20-year average annual loading from the Sacramento Basin (Table 7.1) and should eventually result in a similar proportional decrease in sediment mercury concentrations. Inorganic mercury load reductions elsewhere have resulted in decreases in fish tissue methylmercury concentrations (Table 3.1). It is expected that similar reductions in fish tissue concentration also will occur in the Delta once the mercury content of its sediment decreases. Proposed total mercury load reductions are described in Section 8.2, after Tables 8.4a through 8.4g.

Table 8.4a: Allocations for Methylmercury Sources to the Central Delta Subarea

MeHg Source	Tributary or Permittee	Permit #	Existing Average Annual MeHg Conc. (ng/l)	Existing Average Annual MeHg Load (g/yr)	Percent Allocation	MeHg Conc. Used to Calculate Allocation (ng/l)	MeHg Load/ Wasteload Allocation (g/yr)
LOAD ALLOCATIONS							
Agricultural Drainage			*NA* [(a)]	37	100%	*NA*	37
Atmospheric Deposition			*NA*	7.3	100%	*NA*	7.3
Open Water Habitats			*NA*	370	100%	*NA*	370
Wetland Habitats			*NA*	210	100%	*NA*	210
Tributary Inputs	Bear/Mosher Creeks		0.31	11	100%	0.31	11
	Calaveras River		0.14	26	100%	0.14	26
Urban runoff (nonpoint source)			0.24	0.14	100%	0.24	0.14
WASTELOAD ALLOCATIONS							
NPDES Facilities	Discovery Bay WWTP	CA0078590	0.18	0.37	100%	0.18	0.37
	Lodi White Slough WWTP	CA0079243	0.15	0.93	100%	0.15	0.93
	San Joaquin Co DPW CSA 31-Flag City WWTP	CA0082848	0.08	0.0066	100%	0.08	0.0066
	Unassigned WWTP allocation [(b)]		*NA*	*NA*	100%	0.06	0.31
NPDES MS4s	Contra Costa (County of)	CAS083313	0.24	0.75	100%	0.24	0.75
	Lodi (City of)	CAS000004	0.24	0.053	100%	0.24	0.053
	Port of Stockton MS4	CAS084077	0.24	0.39	100%	0.24	0.39
	San Joaquin (County of)	CAS000004	0.24	0.57	100%	0.24	0.57
	Stockton Area MS4	CAS083470	0.24	3.6	100%	0.24	3.6
CENTRAL DELTA SUBAREA TOTAL:			**0.060**	**668**	**100%**	**0.060**	**668**

(a) NA: not applicable.

(b) To account for the projected population growth in the Delta region, the Central Delta subarea TMDL contains an unassigned wasteload allocation for new municipal WWTP discharges based on an average methylmercury concentration of 0.06 ng/l and discharge volume equal to 60% of existing WWTP discharges in the subarea (see Table 8.3).

Table 8.4b: Allocations for Methylmercury Sources to the Marsh Creek Subarea

MeHg Source	Tributary or Permittee	Permit #	Existing Average Annual MeHg Conc. (ng/l)	Existing Average Annual MeHg Load (g/yr)	Percent Allocation	MeHg Conc. Used to Calculate Allocation (ng/l)	MeHg Load/ Wasteload Allocation (g/yr)
LOAD ALLOCATIONS							
Agricultural Drainage			*NA*	2.2	17%	*NA*	0.37
Atmospheric Deposition			*NA*	0.23	100%	*NA*	0.23
Open Water Habitats			*NA*	0.18	17%	*NA*	0.031
Wetland Habitats			*NA*	0.34	17%	*NA*	0.058
Tributary Inputs	Marsh Creek		0.25	1.9	18%	0.05	0.34
WASTELOAD ALLOCATIONS							
NPDES Facilities	Brentwood WWTP [(a)]	CA0082660	0.02	0.086	160%	0.02	0.14
NPDES Facilities	Unassigned WWTP Allocation [(b)]		*NA*	*NA*	100%	0.06	0.16
NPDES MS4s	Contra Costa (County of)	CAS083313	0.24	1.2	25%	0.06	0.30
MARSH CREEK SUBAREA TOTAL:			**0.224**	**6.1**	**27%**	**0.060**	**1.6**

(a) The City of Brentwood WWTP has an existing average effluent methylmercury concentration less than 0.06 ng/l and therefore has a wasteload allocation based on its existing average effluent methylmercury concentration and a discharge volume equal to 160% of its existing volume (See Table 8.3).

(b) To account for the projected population growth in the Delta region, the Marsh Creek subarea TMDL contains an unassigned wasteload allocation for new municipal WWTP discharges based on an average methylmercury concentration of 0.06 ng/l and discharge volume equal to 60% of existing WWTP discharges in the subarea (see Table 8.3).

Table 8.4c: Allocations for Methylmercury Sources to the Mokelumne/Cosumnes Rivers Subarea

MeHg Source	Tributary or Permittee	Permit #	Existing Average Annual MeHg Conc. (ng/l)	Existing Average Annual MeHg Load (g/yr)	Percent Allocation	MeHg Conc. Used to Calculate Allocation (ng/l)	MeHg Load/ Wasteload Allocation (g/yr)
LOAD ALLOCATIONS							
Agricultural Drainage			*NA*	1.6	51%	*NA*	0.82
Atmospheric Deposition			*NA*	0.29	100%	*NA*	0.29
Open Water Habitats			*NA*	4.0	100%	*NA*	4.0
Wetland Habitats			*NA*	30	51%	*NA*	15
Tributary Inputs	Mokelumne River		0.17	110	30%	0.05	33
Urban (nonpoint source)			0.24	0.018	100%	0.24	0.018
WASTELOAD ALLOCATIONS							
NPDES MS4s	San Joaquin (County of)	CAS000004	0.24	0.045	51%	0.12	0.023
MOKELUMNE/COSUMNES RIVERS SUBAREA TOTAL:			**0.166**	**146**	**36%**	**0.060**	**53**

Table 8.4d: Allocations for Methylmercury Sources to the Sacramento River Subarea

MeHg Source	Tributary or Permittee	Permit #	Existing Average Annual MeHg Conc. (ng/l)	Existing Average Annual MeHg Load (g/yr)	Percent Allocation	MeHg Conc. Used to Calculate Allocation (ng/l)	MeHg Load/ Wasteload Allocation (g/yr)
LOAD ALLOCATIONS							
Agricultural Drainage			*NA*	36	56%	*NA*	20
Atmospheric Deposition			*NA*	5.6	100%	*NA*	5.6
Open Water Habitats			*NA*	140	100%	*NA*	140
Wetland Habitats			*NA*	94	56%	*NA*	53
Tributary Inputs	Morrison Creek		0.10	7.5	50%	0.05	3.8
	Sacramento River [(a)]		0.10	2,026	52.35%	0.05	1,061 [(a)]
Urban (nonpoint source)			0.24	0.62	100%	0.24	0.62
WASTELOAD ALLOCATIONS							
NPDES Facilities	Rio Vista WWTP	CA0079588	0.16	0.10	56%	0.09	0.056
	Rio Vista Northwest WWTP [(b)]	CA0083771	*To be determined.* [(b)]				
	Sacramento Combined WWTP [(c)]	CA0079111	0.24	0.43	56%	0.13	0.24
	SRCSD Sacramento River WWTP	CA0077682	0.72	160	56%	0.40	90
	SRCSD Walnut Grove WWTP	CA0078794	2.2	0.24	56%	1.23	0.13
	West Sacramento WWTP [(d)]	CA0079171	0.05	0.39	160%	0.05	0.62
	Unassigned WWTP Allocation [(e)]		*NA*	*NA*	100%	0.06	8.4
NPDES MS4s	Rio Vista (City of)	CAS000004	0.24	0.014	56%	0.13	0.0078
	Sacramento Area MS4	CAS082597	0.24	1.8	56%	0.13	1.0
	San Joaquin (County of)	CAS000004	0.24	0.19	56%	0.13	0.11
	Solano (County of)	CAS000004	0.24	0.073	56%	0.13	0.041
	West Sacramento (City of)	CAS000004	0.24	0.65	56%	0.13	0.36
	Yolo (County of)	CAS000004	0.24	0.073	56%	0.13	0.041
SACRAMENTO RIVER SUBAREA TOTAL:			**0.108**	**2,474**	**56%**	**0.060**	**1,385**

(a) Because of its magnitude, the Sacramento River's existing methylmercury load and percent allocation were not rounded to two significant figures before calculating the allocations for point and nonpoint sources in the Sacramento River subarea. Staff recommends that for compliance purposes the Sacramento River's percent allocation and resulting load allocation be rounded to 50% and 1,000 g/yr, respectively.

(b) A methylmercury allocation for the City of Rio Vista's Northwest WWTP (which began discharging after WY2000-2003) will be determined once it completes one year of monthly monitoring of methylmercury in its discharge. If its annual average effluent methylmercury concentration is less than 0.06 ng/l, it will have a methylmercury wasteload allocation equal to its annual average effluent methylmercury concentration multiplied by its maximum rated discharge volume. If its annual average effluent methylmercury concentration is greater than 0.06 ng/l, it will have a methylmercury wasteload allocation based on a concentration reduction of 44%. If such a reduction would result in an average discharge methylmercury concentration less than 0.06 ng/l, it will have a wasteload allocation based on a methylmercury concentration of 0.06 ng/l. Its wasteload allocation is a component of the "Unassigned WWTP Allocation".

(c) The methylmercury wasteload allocation for the Sacramento Combined WWTP (CA0079111) WWTP is based on the average methylmercury concentration observed in wet weather urban runoff (0.24 ng/l) and the WWTP's average annual discharge volume (464 million gallons per year / 1.3 mgd). The allocation will be re-evaluated after the Sacramento Combined WWTP conducts one year of discharge methylmercury monitoring.

(d) The City of West Sacramento WWTP has an existing average effluent methylmercury concentration less than 0.06 ng/l and therefore has a wasteload allocation based on its existing average effluent methylmercury concentration and a discharge volume equal to 160% of its existing volume (See Table 8.3).

(e) To account for the projected population growth in the Delta region, the Sacramento River subarea TMDL contains an unassigned wasteload allocation for new municipal WWTP discharges based on an average methylmercury concentration of 0.06 ng/l and discharge volume equal to 60% of existing WWTP discharges in the subarea (see Table 8.3).

Table 8.4e: Allocations for Methylmercury Sources to the San Joaquin River Subarea

MeHg Source	Tributary or Permittee	Permit #	Existing Average Annual MeHg Conc. (ng/l)	Existing Average Annual MeHg Load (g/yr)	Percent Allocation	MeHg Conc. Used to Calculate Allocation (ng/l)	MeHg Load/ Wasteload Allocation (g/yr)
LOAD ALLOCATIONS							
Agricultural Drainage			*NA*	23	25%	*NA*	5.8
Atmospheric Deposition			*NA*	2.7	100%	*NA*	2.7
Open Water Habitats			*NA*	48	100%	*NA*	48
Wetland Habitats			*NA*	43	25%	*NA*	11
Tributary Inputs	French Camp Slough		0.14	11	36%	0.05	4.0
	San Joaquin River [(a)]		0.16	356	31%	0.05	110
Urban (nonpoint source)			0.24	0.0022	100%	0.24	0.0022
WASTELOAD ALLOCATIONS							
NPDES Facilities	Deuel Vocational Institute WWTP (b)	CA0078093	0.02	0.013	160%	0.02	0.021
	Manteca WWTP [(c)]	CA0081558	0.22	1.4	27%	0.06	0.38
	Oakwood Lake Subdivision Mining Reclamation [(b)]	CA0082783	0.03	0.38	100%	0.03	0.38
	Stockton WWTP	CA0079138	0.94	36	25%	0.24	9.0
	Tracy WWTP [(c)]	CA0079154	0.14	1.8	43%	0.06	0.77
	Unassigned WWTP Allocation [(d)]		*NA*	*NA*	100%	0.06	2.2
NPDES MS4s	Lathrop (City of)	CAS000004	0.24	0.27	25%	0.06	0.068
	Port of Stockton MS4	CAS084077	0.24	0.010	25%	0.06	0.0025
	San Joaquin (County of)	CAS000004	0.24	2.2	25%	0.06	0.55
	Stockton Area MS4	CAS083470	0.24	0.50	25%	0.06	0.13
	Tracy (City of)	CAS000004	0.24	1.8	25%	0.06	0.45
SAN JOAQUIN RIVER SUBAREA TOTAL:			**0.160**	**528**	**37%**	**0.060**	**195**

(a) Because of its magnitude, the San Joaquin River's existing methylmercury load was not rounded to two significant figures before calculating the allocations for point and nonpoint sources in the San Joaquin River subarea. Coincidently, the San Joaquin River's resulting load allocation was 110 g/yr, which does not require rounding to have two significant digits.

(b) The Deuel Vocational Institute WWTP and Oakwood Lake Subdivision Mining Reclamation discharges have existing average effluent methylmercury concentrations less than 0.06 ng/l. Therefore, the Deuel Vocational Institute WWTP wasteload allocation is based on its existing average effluent methylmercury concentration and a discharge volume equal to 160% of its existing volume (See Table 8.3). The Oakwood Lake Subdivision Mining Reclamation wasteload allocation is based on its existing average effluent methylmercury concentration and average discharge volume. Its discharge is from flood-control pumping from Oakwood Lake, a former excavation pit filled primarily by groundwater, to the San Joaquin River. Discharge volumes and associated methylmercury loads are expected to fluctuate between wet and dry years.

(c) The first iteration of the "percent allocation" calculations resulted in "MeHg Concentration Used to Calculate Allocation" less than 0.06 ng/l for the Manteca and Tracy WWTPs. Therefore, the Manteca and Tracy WWTPs wasteload allocations are based on methylmercury concentrations of 0.06 ng/l, which correspond to percent allocations of 27% and 43%, respectively.

(d) To account for the projected population growth in the Delta region, the San Joaquin River subarea TMDL contains an unassigned wasteload allocation for new municipal WWTP discharges based on an average methylmercury concentration of 0.06 ng/l and discharge volume equal to 60% of existing WWTP discharges in the subarea (see Table 8.3).

Table 8.4f: Allocations for Methylmercury Sources to the West Delta Subarea

MeHg Source	Tributary or Permittee	Permit #	Existing Average Annual MeHg Conc. (ng/l)	Existing Average Annual MeHg Load (g/yr)	Percent Allocation	MeHg Conc. Used to Calculate Allocation (ng/l)	MeHg Load/ Wasteload Allocation (g/yr)
LOAD ALLOCATIONS							
Agricultural Drainage			*NA*	4.1	100%	*NA*	4.1
Atmospheric Deposition			*NA*	2.4	100%	*NA*	2.4
Open Water Habitats			*NA*	190	100%	*NA*	190
Wetland Habitats			*NA*	130	100%	*NA*	130
Urban (nonpoint source)			0.24	0.066	100%	0.24	0.066
WASTELOAD ALLOCATIONS							
NPDES Facilities	GWF Power Systems [(a)]	CA0082309	0.03	0.0019	100%	0.03	0.0052
	Unassigned WWTP Allocation [(b)]		*NA*	*NA*	100%	0.06	0.57
NPDES MS4s	Contra Costa (County of)	CAS083313	0.24	3.2	100%	0.24	3.2
WEST DELTA SUBAREA TOTAL:			**0.083 (a)**	**330**	**100%**	**0.060**	**330**

(a) GWF Power Systems (CA0082309), in the West Delta subarea, acquires its intake water from sources other than ambient surface water and therefore was incorporated in the allocation calculations. GWF effluent methylmercury concentrations are less than the analytical method detection limit (0.03 ng/l; see Table 6.5 in Chapter 6). As a result, staff recommends that its allocation be equal to an annual load of 0.0052 g/yr, calculated by using the methylmercury method detection limit (0.03 ng/l) and its design flow (0.125 mgd) to accommodate expected growth.

(b) To account for projected population growth in the Delta region, the West Delta subarea TMDL contains an unassigned wasteload allocation for new municipal WWTP discharges. There are no WWTPs currently in the West Delta subarea. However, as noted in Table 8.3a, the Ironhouse Sanitary District WWTP is expected to begin discharging to the San Joaquin River sometime in 2009 with a permitted maximum discharge of 4.3 mgd. To account for the Ironhouse discharge and any population growth in the West Delta subarea, staff based the unassigned wasteload allocation (0.57 g/yr) on the "Effluent Volume Predicted to Be Discharged by New WWTPs" for the West Delta subarea (6.9 mgd) and an average methylmercury concentration of 0.06 ng/l. The additional 0.57 g/yr loading should not cause an exceedance of the proposed fish tissue objectives in the West Delta subarea because (1) it is based on the methylmercury goal for ambient water (0.06 ng/l), which includes a 10% margin of safety, and (2) West Delta fish tissue and ambient water methylmercury levels are expected to decrease when actions are implemented to reduce water methylmercury levels in the Sacramento River and Yolo Bypass subareas (e.g., by 44 to 80%), inflows which dominate the West Delta subarea.

Table 8.4g: Allocations for Methylmercury Sources to the Yolo Bypass Subarea

MeHg Source	Tributary or Permittee	Permit #	Existing Average Annual MeHg Conc. (ng/l)	Existing Average Annual MeHg Load (g/yr)	Percent Allocation	MeHg Conc. Used to Calculate Allocation (ng/l)	MeHg Load/ Wasteload Allocation (g/yr)
LOAD ALLOCATIONS							
Agricultural Drainage			*NA*	19	15%	*NA*	2.9
Atmospheric Deposition			*NA*	4.2	100%	*NA*	4.2
Open Water Habitats			*NA*	100	15%	*NA*	15
Wetland Habitats			*NA*	480	15%	*NA*	72
Tributary Inputs	Cache Creek Settling Basin Outflow		0.50	140	10%	0.05	14
	Dixon Area		0.24	3.6	21%	0.05	0.76
	Fremont Weir		0.10	180	50%	0.05	90
	Knights Landing Ridge Cut		0.19	100	26%	0.05	26
	Putah Creek		0.18	11	28%	0.05	3.1
	Ulatis Creek		0.24	9.5	21%	0.05	2.0
	Willow Slough		0.24	18	21%	0.05	3.8
WASTELOAD ALLOCATIONS							
NPDES Facilities	Davis WWTP [(a)]	CA0079049	0.61	0.78	15%	0.09	0.12
	Woodland WWTP [(b)]	CA0077950	0.03	0.25	160%	0.03	0.40
	Unassigned WWTP Allocation [(c)]		*NA*	*NA*	100%	0.06	0.42
NPDES MS4s	Solano (County of)	CAS000004	0.24	0.085	25%	0.06	0.021
	West Sacramento (City of)	CAS000004	0.24	1.1	25%	0.06	0.28
	Yolo (County of)	CAS000004	0.24	0.33	25%	0.06	0.083
YOLO BYPASS [North & South] SUBAREA TOTAL:			**0.273**	**1,069**	**22%**	**0.060**	**235**

(a) The City of Davis WWTP (CA0079049) has two discharge locations; wastewater is discharged from Discharge 001 to the Willow Slough Bypass upstream of the Yolo Bypass and from Discharge 002 to the Conaway Ranch Toe Drain in the Yolo Bypass. The methylmercury load allocation listed in this table applies only to Discharge 002, which discharges seasonally from about February to June. Discharge 001 is encompassed by the Willow Slough watershed methylmercury allocation.

(b) The City of Woodland WWTP has an existing average effluent methylmercury concentration less than 0.06 ng/l and therefore has a wasteload allocation based on its existing average effluent methylmercury concentration and a discharge volume equal to 160% of its existing volume (See Table 8.3).

(c) To account for the projected population growth in the Delta region, the Yolo Bypass subarea TMDL contains an unassigned wasteload allocation for new municipal WWTP discharges based on an average methylmercury concentration of 0.06 ng/l and discharge volume equal to 60% of existing WWTP discharges in the subarea (see Table 8.3).

8.2 Total Mercury Load Limits for Tributary Watersheds

Staff recommends that total mercury limits be implemented in addition to the methylmercury allocations for three reasons: (1) to maintain compliance with the USEPA's criterion of 50 ng/l for total mercury in the water column; (2) to prevent increases in total mercury discharges from causing increases in aqueous and fish methylmercury in the Delta, thereby worsening the impairment; and (3) to meet the San Francisco Bay TMDL allocation to the Central Valley. The TMDL for San Francisco Bay assigned the Central Valley a five-year average total mercury load allocation of 330 kg/yr or a decrease of 110 kg/yr (Section 2.4.2.3).

The total mercury source analysis described in Chapter 7 indicates that almost all the total mercury loading to the Delta and Yolo Bypass comes from tributary inputs. As described in Chapter 4 of the draft Basin Plan Amendment staff report, staff recommends that total mercury load limits be applied to the tributary inputs (which are comprised almost entirely of nonpoint sources) and total mercury concentration limits and pollution prevention measures be implemented by point sources that are likely to increase due to population growth. This section of the TMDL report reviews how the total mercury load limits were calculated for key tributary watersheds.

A reduction of 110 kg/yr represents about a 28% decrease in the 20-year average annual loading[48] from Delta tributaries (Table 7.1). As described in Chapter 4 of the draft Basin Plan Amendment staff report, staff recommends that the 110 kg total mercury reduction be met by reductions in total mercury entering the Delta from the Sacramento Basin. Reduction efforts should focus in the Cache Creek, Feather River, American River, and Putah Creek watersheds (Table 8.5) because these watersheds export the largest volume of highly contaminated sediment (see Tables 7.5 and 7.17 in Chapter 7). Staff recommends that the proposed total mercury reductions for the Sacramento Basin tributaries be based on WY1984-2003 average annual loads. This 20-year period includes a mix of wet and dry years that is statistically similar to what has occurred in the Sacramento Basin over the last 100 years. The proposed reductions will enable Delta waters to maintain compliance with the CTR criterion of 50 ng/l (Section 7.4 in Chapter 7).

The Cache Creek Settling Basin (CCSB) is a 3,600-acre structure located at the base of the Cache Creek watershed. The U.S. Army Corp of Engineers initially constructed the CCSB in 1937 to contain sediment and maintain the flood capacity of the Yolo Bypass. The CCSB was modified in 1993 to increase its sediment trapping efficiency. However, no provision was made for removing the additional trapped material. Most of the mercury in Cache Creek is transported on sediment. Therefore, an increase in sediment trapping also results in deposition and retention of mercury. The CCSB currently traps about half of the sediment and mercury transported by Cache Creek (Foe and Croyle, 1998; CDM, 2004; Cooke *et al.*, 2004; CDM, 2004; Appendices F and I). The rest is exported to the Delta through the Yolo Bypass. Currently, the CCSB receives about 224 kg/yr from the Cache Creek watershed and discharges about 118 kg/yr to the Yolo Bypass. The sediment/mercury trapping efficiency of the CCSB is expected to decrease as it fills and may reach zero in about 35 years unless a maintenance

[48] Year-to-year loads are expected to fluctuate with water volume and other environmental factors.

program is instituted to periodically remove material (CDM, 2004). A non-operational CCSB would result in a mercury discharge to the Yolo Bypass and Delta of about 224 kg/yr, an addition of 106 kg/yr mercury loading (Table 7.6b).

Two sets of actions are considered in the draft Basin Plan Amendment staff report (Chapter 4 and Appendix C) for the Cache Creek Settling Basin that would reduce mercury discharges to the Yolo Bypass and Delta. First, mercury loads entering the CCSB from the Cache Creek watershed could be reduced. The Basin Plan Amendment for control of mercury in Cache Creek was adopted by the Central Valley Water Board in October 2005. Implementation actions described in the Basin Plan Amendment report would reduce mercury loads *entering* the Cache Creek Settling Basin by about 60 kg/year (Cooke and Morris, 2005), from a 20-year average of 224 kg/yr to 164 kg/yr. Given a modeled basin trapping efficiency of about 64% (CDM, 2004, Table 4-3), the watershed implementation actions would reduce basin total mercury mass discharges to the Yolo Bypass by 32 kg/yr. Approximately 25 kg of the 60 kg/year reduction in the Cache Creek watershed may come from instituting control programs at all major mercury mines in the watershed.[49] The remainder of the reduction will be achieved by control of erosion in mercury-enriched areas and by remediation/removal of contaminated floodplain sediment in the Cache Creek canyon and in Bear Creek. However, most the total mercury load now leaving the CCSB appears to originate from erosion of mercury contaminated sediment in the active flood plain downstream of the mines. Studies are required by the Cache Creek mercury control program to evaluate in-stream sediment control options. It is unclear whether environmentally acceptable, cost effective control programs can be developed to significantly curtail the movement of this material.

As result, a second set of actions could focus on decreasing the mercury load leaving the Cache Creek Settling Basin. A program should be instituted to (a) periodically excavate the material presently accumulating in the CCSB, and (b) make additional modifications to the CCSB to increase trapping efficiency. Initial modeling results indicate that CCSB operation and design could be modified to improve the sediment and mercury mass trapping efficiency of the CCSB from 64% to 75% (CDM, 2004, Table 4-3, Alternative 5 - Excavate and Raise Weir Early). Decreasing mercury inputs to the CCSB to 164 kg/yr through the watershed control program and increasing the trapping efficiency of the CCSB to 75% results in an export to the Yolo Bypass of 41 kg/yr, which represents a decrease of 77 kg/yr from current loading. This reduction is approximately 70% of the 110-kg/yr reduction required by the San Francisco Bay mercury TMDL.

The remaining 33 kg/yr reduction required to achieve a 110 kg/yr reduction in Central Valley total mercury loading to San Francisco Bay is assigned to the sum of the mercury loads leaving the Feather River, American River and Putah Creek watersheds (90 kg/yr, Table 8.5). This equates to a reduction of 37% and an acceptable load of 57 kg/yr leaving these three watersheds. Monitoring is underway to identify sources of methyl and total mercury in these and the other Sacramento Basin tributary watersheds. Specific limits for the Feather River, American River and Putah Creek watersheds are not defined in Table 8.5 to allow for greater flexibility in developing future implementation strategies. However, the sum of the load reductions for these watersheds and Cache Creek Settling Basin outflow must equal 110 kg/yr.

[49] The mines are located in Harley Gulch, Sulfur and Bear Creeks and Clear Lake.

Each of these watersheds contains waterways already identified on the CWA Section 303(d) List as impaired by mercury. Hence, each will be the focus of future watershed-specific TMDL programs. Specific load reductions for each watershed will be specified in its TMDL report.

A 110 kg reduction in total mercury from the Sacramento Basin is a reasonable goal for the first phase of the Delta mercury control program. For example, Feather River and Cache Creek Settling Basin outflows have average methylmercury concentrations of 0.10 and 0.50 ng/l, respectively (see Appendix F for a summary of available methylmercury concentration data provided in Appendix L). If Feather River and Cache Creek watershed outflow methylmercury concentrations need to be reduced to 0.05 ng/l to enable compliance with the methylmercury allocations for Fremont Weir and Cache Creek Settling Basin discharges, they would require reductions of 50% and 90%, respectively. If the proposed source characterization and control studies find no means to reduce aqueous methylmercury by methods other than total mercury reduction, than the total mercury exports from the Feather River (67 kg/yr) and CCSB (118 kg) may require reductions of a similar magnitude. A 50% reduction of Feather River watershed total mercury outflows is about 34 kg/yr, and an 90% reduction of CCSB exports is about 106 kg/yr, totaling about 140 kg/yr.

Table 8.5: Total Mercury Load Limits for Key Sacramento Basin Tributaries

Tributary	**Existing Annual TotHg Load** [a] (kg/yr)	**Required Reduction** (kg/yr)	**Acceptable TotHg Load** (kg/yr)
Cache Creek Settling Basin Outflow	118	77	41
American River	14		
Feather River	67	33	57
Putah Creek	8.8		
TOTAL:	**208**	**110**	**98**

(a) Existing annual TotHg loads represent the average annual loads estimated for WY1984-2003. This 20-year period includes a mix of wet and dry years that is statistically similar to what has occurred in the Sacramento Basin over the last 100 years. Annual loads are expected to fluctuate with water volume and other factors.

8.3 Margin of Safety

Implicit and explicit margins of safety are included in the aqueous methylmercury goal for the Delta. In addition, while not a direct margin of safety, the implementation plan (Chapter 4 in the draft Basin Plan Amendment staff report) calls for updated fish advisories in the Delta and an expanded outreach program to educate humans fishing in the Delta.

The proposed aqueous methylmercury goal of 0.06 ng/l (Chapter 5) incorporates an explicit margin of safety of approximately 10%. The linkage analysis (Section 5.2) predicted a safe level of 0.066 ng/l for average aqueous methylmercury, from which 0.006 was subtracted to provide a margin of safety.

In addition, there is an implicit margin of safety for wildlife species that consume Delta fish. As outlined in the previous paragraph, the aqueous methylmercury goal corresponds to 0.24 mg/kg mercury in large TL4 fish, which was calculated for the protection of humans consuming about one meal per week. As shown in Table 4.9 (Chapter 4), the wildlife targets for smaller and lower trophic level fish correspond to large TL4 fish mercury levels that range from 0.30 mg/kg (for Western grebe) to 1.12 mg/kg (for Western snowy plover). These values correspond to 350-mm largemouth bass mercury levels of 0.31 and 1.34 mg/kg. When entered into the regression equation for largemouth bass and unfiltered average aqueous methylmercury (Figure 5.2[A]), these values translate to aqueous methylmercury concentrations of 0.08 ng/l and 0.19 ng/l, allowing a margin of safety of 25% or more, depending on the wildlife species.

8.4 Seasonal & Inter-annual Variability

8.4.1 Variability in Aqueous Methyl and Total Mercury

Mercury loads in Delta tributary inputs fluctuate because of seasonal and inter-annual variation. Winter precipitation increases the sediment and total mercury loads entering the Delta through erosion and re-suspension of sediment. Most of the total mercury coming from tributaries and direct surface runoff enters the Delta during high flow events. In contrast, methylmercury production is typically higher during the summer months. In addition, greater mercury loads enter the Delta during wet water years.

Seasonal and inter-annual variability in methylmercury loads were accounted for in the source analysis and methylmercury load allocations by evaluating annual average loads for Delta sources and losses for WY2000 to 2003, a relatively dry period that encompasses the available concentration data for the major Delta inputs and exports. Twenty-year average, annual loads of total mercury were estimated for tributary loads based on flow and precipitation records for WY1984-2003. This 20-year period includes a mix of wet and dry years that is statistically similar to what has occurred in the Sacramento Basin over the last 100 years. However, insufficient data were available to estimate 20-year average annual loads for methylmercury sources. Methylmercury allocations and total mercury limits will be re-evaluated as additional information becomes available. Future monitoring programs will accommodate long-term inter-annual variability by evaluating whether sources are meeting allocations on a multi-year basis.

8.4.2 Variability in Biota Mercury

Seasonal and inter-annual variation also occurs in biota. Slotton and others (2003) found that Delta species exhibited both seasonal and inter-annual variability in mercury body burden. Corbicula (clams) had higher mercury concentrations in the spring while inland silversides (representative forage fish species) were higher in fall. In addition, silverside bioaccumulation was greater in 1998 than in 1999 and 2000 at many locations in the Delta. Davis and others (2002) measured higher mercury concentrations in similar sized largemouth bass in 1999 than in 2000. The researchers noted that the winter of 1997 was very wet and speculated that the high flows may have introduced significant quantities of “new” mercury that was methylated and incorporated into forage fish in 1998. Predacious fish like largemouth bass, which feed upon silversides, took an additional year to reflect the higher methylmercury concentrations.

Seasonal and inter-annual variability in large fish was accounted for in the numeric targets and linkage analysis by using data collected over multiple years. Future monitoring will accommodate seasonal and inter-annual variability by sampling large fish about every ten years.

8.4.3 Regional and Global Change

Several ongoing regional and global changes may affect methyl and total mercury loading in the Delta. This section identifies several of these.

8.4.3.1 Population Growth

The Delta and its tributary watersheds are experiencing substantial population growth. Population in the Central Valley increased by about 20% between 1990 and 2000 (AFT, 2006; CDOF, 2004). This resulted in the conversion of about 98,000 acres of agricultural land to urban uses (AFT, 2006). Four of the five fastest growing cities in the Sacramento Valley are located within about one day's travel time (about 20 to 30 miles by water) of the Delta. The California Department of Finance predicts that populations in the Delta/Yolo Bypass counties[50] will increase 76% to 213% by 2050 (CDOF, 2007), with an average increase of about 120%.

Increasing populations will result in increased discharges from municipal wastewater treatment plants. In addition, urbanization increases both volume and discharge velocity of runoff because of the increase in impervious surfaces. Urbanization also tends to increase pollutant loading because impervious surfaces neither absorb water nor remove pollutants, and urban development tends to create new anthropogenic mercury pollution sources. As Chapters 6 and 7 indicate, urban runoff in the Sacramento, Stockton and Tracy areas has higher methylmercury and total mercury concentrations than ambient river concentrations. However, little is known about how the conversion of agricultural land to urban uses affects methylmercury concentration.

MS4 allocations apply to all urban acreage within MS4 service areas within each Delta subarea and apply to the sum of methylmercury loads in existing urban acreage runoff and in runoff from future urbanized lands within the MS4 service areas. Staff assumed that, in general, NPDES-permitted municipal WWTP discharges throughout the Delta/Yolo Bypass would increase by 120%. Staff assumed that half of that growth will be addressed by expansions to existing facilities in each Delta subarea, and that half will be serviced by new facilities in each subarea. As described in Section 8.1.2 and shown in Tables 8.3 and 8.4, the allocation strategy incorporates the assumption that existing municipal WWTPs will increase their discharge volumes by 60% and reserves assimilative capacity for new WWTP discharges.

Chapter 4 in the draft Basin Plan Amendment staff report reviews possible implementation strategies to address the methylmercury allocations and total mercury limits for municipal WWTP discharges and urban runoff in the Delta region.

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[50] The CDOF predicts the following population increases by 2050: Contra Costa County - 89%, Sacramento County - 76%, San Joaquin County - 213%, Solano County - 105%, and Yolo County - 93% (CDOF, 2007).

8.4.3.2 Restoration of Wetlands

Research conducted in the Delta and elsewhere has found that wetlands are efficient sites for methylmercury production. There are currently about 26,600 acres of wetlands within the Delta/Yolo Bypass (USFWS, 2006). The Record of Decision for the CALFED Bay-Delta Program commits it to restore 30,000 to 45,000 acres of fresh, emergent tidal wetlands, 17,000 acres of fresh, emergent nontidal wetlands, and 28,000 acres of seasonal wetlands in the Delta by 2030 (CALFED Bay-Delta Program, 2000a). This is a total of 75,000 to 90,000 acres of additional seasonal and permanent wetlands in the Delta, which represents about a three to four times increase in wetland acreage from current conditions. Many of the proposed restoration sites are downstream of mercury-enriched watersheds. Marsh restoration efforts below mercury enriched watersheds are proposed for the following locations: Yolo Bypass downstream of Cache and Putah Creeks; Dutch Flats downstream of the Mount Diablo Mercury mine in the Marsh Creek watershed; and Staten Island and the Cosumnes River Wildlife Refuge near the confluence of the Cosumnes River and Mokelumne River.

Mass balance calculations indicated that methylmercury flux from wetland sediments may account for approximately 983 g/year of methylmercury (see Table 6.2 in Chapter 6), or about 19% of the total methylmercury budget for the Delta. A doubling to tripling in methylmercury loading from wetland sediments could increase overall Delta loading by about 16 to 27%. The linkage relationship suggests that such an increase could result in a 28 to 48% increase in mercury concentrations in standard 350-mm largemouth bass (Figure 5.3). Chapter 4 in the draft Basin Plan Amendment staff report provides a description of staff's suggested Central Valley Water Board policy for new wetland creation.

8.4.3.3 Decreasing Sediment Loads

The sediment load in the Sacramento River decreased by about 50% between 1957 and 2001 (Wright and Schoellhamer, 2004). The decrease is believed to be caused by the trapping of sediment in reservoirs, a decrease in erodible material from hydraulic mining, changes in land use, and construction of levees (Wright and Schoellhamer, 2004; James, 2004). Mercury loads are likely to have also decreased during the same period because much of the inorganic mercury is transported on sediment particles. It is not known what the magnitude of the decrease in mercury loading has been and whether it will continue in the future. The decrease in sediment loading suggests that the relative proportion of erodible material from upstream watersheds may also be changing. The present 20-year volume-weighted average mercury to TSS ratio of sediment entering the Delta is approximately 0.18 mg/kg. This value may change depending on the new sources of sediment. The mercury content of surficial sediment is important, as it is one of the major factors controlling methylmercury production. Methylmercury production in Delta/Yolo Bypass sediment now accounts for about 36% of the methylmercury in the Delta (Figure 6.11). It is not clear how this proportion may change in the future.

8.4.3.4 Climate Change

Recent studies indicate that global warming may disrupt traditional weather and run-off patterns and increase the frequency and severity of summer droughts and springtime flooding (Brekke *et al.*, 2004; Knowles and Cayan, 2002; Miller *et al.*, 2003; Service, 2004; Stewart *et al.*, 2004). Trends over the last 50 years indicate that more precipitation in the Sierra Nevada Mountains is occurring as rain, and that snow is melting earlier in the spring, resulting in a reduced snow pack and less water in reservoirs in the summer and fall. Climate models suggest that these trends may become more pronounced with continued warming. The net result may have unpredictable consequences on ecological processes in the Delta including the synthesis and bioaccumulation of methylmercury. The source analyses, linkage analysis, methylmercury allocations and total mercury limits described in this TMDL are based on present climate conditions. Staff will re-evaluate linkage relationships associated with changing environmental conditions as more information becomes available in the future.

Key points and options to consider are summarized on the following two pages.

Key Points

- Methylmercury allocations are divided among “wasteload allocations” for point sources and “load allocations” for nonpoint sources. The TMDL is the sum of these components. The allocation strategy used in this chapter is based on staff’s recommended strategy described in Chapter 4 of the draft Basin Plan Amendment staff report and is designed to remedy the beneficial use impairment in all subareas of the Delta. Total mercury limits were developed to maintain compliance with the USEPA’s CTR for total mercury in the water column and to achieve the San Francisco Bay mercury control program’s total mercury allocation for the Central Valley, as well as to help enable methylmercury reductions in Delta water and fish.

Methylmercury:

- Methylmercury allocations were made in terms of the existing assimilative capacity of the different Delta subareas. The recommended goal for ambient water is an average annual concentration of 0.06 ng/l methylmercury in unfiltered water (Chapter 5). This goal describes the assimilative capacity of Delta waters in terms of concentration and encompasses a margin of safety of approximately 10%. Central Valley Water Board staff anticipates that as the average concentration of methylmercury in each Delta subarea decreases to the aqueous goal, the targets for fish tissue will be attained.
- To determine necessary reductions, the existing average aqueous methylmercury levels in ambient water in the Delta subareas were compared to the methylmercury goal. The amount of reduction needed in each subarea is expressed as a percent of the existing concentration. Percent reductions required to meet the goal ranged from 0% in the Central Delta subarea to more than 70% in the Yolo Bypass and Mokelumne River subareas.
- Central Valley Water Board staff recommends that sources with existing or allocated average methylmercury concentrations at or below 0.06 ng/l be considered dilution and assigned wasteload allocations that entail no net increase in methylmercury concentration.

Total Mercury:

- Central Valley Water Board staff recommends that the 110 kg total mercury reduction allocated by the San Francisco Bay mercury control program to the Central Valley be met by reductions in total mercury entering the Delta from the Cache Creek, Feather River, American River and Putah Creek watersheds in the Sacramento Basin. These watersheds have both relatively large mercury loadings and high mercury to TSS ratios, which makes them likely candidates for load reduction programs. Additional reductions may be recommended in future phases of the Delta mercury implementation program to meet the proposed methylmercury goal for ambient Delta waters.

Options to Consider

- The methylmercury allocations described in this chapter reflect the preferred implementation alternative described in Chapter 4 of the draft Basin Plan Amendment staff report and are designed to address the beneficial use impairment in all subareas of the Delta. However, as described in the draft Basin Plan Amendment staff report, a number of alternatives are possible. The Central Valley Water Board will consider a variety of allocation strategies and implementation alternatives as part of the Basin Plan amendment process.
- Likewise, a variety of total mercury reduction strategies are possible. A total mercury load reduction strategy was developed to comply with the San Francisco Bay mercury TMDL allocation for to the Central Valley and the USEPA's criterion for human health protection, and to help enable methylmercury reductions in Delta water and fish. Staff applied the San Francisco Bay TMDL's allocated reduction of 110 kg total mercury reduction to loads from the Cache Creek, Feather River, American River and Putah Creek watersheds because these watersheds export the largest volume of highly contaminated sediment while within-Delta sources comprise only a couple percent of total mercury inputs. Chapter 4 of the draft BPA staff report describes additional strategies for minimizing increases from total mercury sources that may increase as a result of population growth and regional water management changes.

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